Foreword

This guide represents another important step in our implementation of Integrated Product and Process Development at ASC. It provides guidance for preparation of RFPs in the area of manufacturing and quality. It deals with these subjects as technical issues that are an integral part of the systems engineering process.

The original version of this guide originated under the Manufacturing Development Initiative during a series of government-industry workshops, sponsored by ASC in 1992. It focused on exploring ways to fundamentally change our acquisition practices to improve our ability to transition programs from development to economical, on-time production. The workshops also identified attributes of a world-class approach to achieving product quality, and suggested a way to motivate our contractors to adopt a quality system that emphasizes the prevention of defects.

What started out as a stand-alone initiative, we now see as a vital set of processes in support of Integrated Product Teams. I have defined *Manufacturing Development* as . . .

" . . . the identification and proper sequencing of technical requirements (including best practices) and verification tasks to ensure that manufacturing and quality considerations are matured consistent with program needs (right things, right time, right place)."

The workshops, and the contents of the first edition, concentrated on the Engineering and Manufacturing Development (EMD) phase of a program because this is where most of our acquisition workload occurs, and is where DoD 5000.2-R has the clearest expectations for change. This current edition expands upon the original. It incorporates the latest acquisition reform initiatives and includes both Pre-EMD Phases (Concept Exploration and Program Definition and Risk Reduction) and the Production Phase, in addition to an updated EMD Phase.

We are continuing to pursue ideas for improving the affordability and quality of systems we acquire. The concept of *Lean Production*, and the specific best practices identified as a result of our joint *Lean Aircraft Initiative* study with industry and MIT will make use of the Manufacturing Development process as an implementing mechanism, and will be included in future revisions to this document as appropriate.

Affordability and quality are issues which are important to every program at ASC. I expect the senior leadership in each SPO to become familiar with the contents of this guide, and to selectively apply these techniques to achieve program objectives.

Lieutenant General, USAF
Commander
Aeronautical Systems Center

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EXECUTIVE SUMMARY

Affordability has become a primary metric for the entire acquisition community, and the failure to achieve affordability now ranks as the number one show stopper for major weapon system programs. In response, numerous initiatives have blossomed under the acquisition reform umbrella, and government and contractor managers and functional experts are struggling to shape them into a cohesive new paradigm which can become a workable reality. The objective is to make the tools and techniques that facilitated the quality revolution in the commercial sector available to defense program customers, contractors, and suppliers.

The Manufacturing Development Guide (MDG) addresses various cost-effective industrial practices which, when intelligently integrated, constitute the essential core of an effective new approach to acquisition strategy. It thus describes a set of fundamental changes in traditional defense systems acquisition practice. It fully supports acquisition reform, although it is not an acquisition reform initiative per se.

One of the most important objectives of the MDG is integrating manufacturing engineering considerations directly into the *development* phases of weapons system acquisitions. In doing so the MDG promotes a clear understanding of the significant design and manufacturing decisions that are made very early in the development process—and the substantial program costs and risks associated with these decisions. The result is that issues which are critical to affordability, to schedule, and to product performance can be considered in a balanced way from the very beginning, at a point when ultimate program outcomes can still be most affected.

A perplexing problem confronting program managers today is how to convey in the RFP the desire for contractors to utilize MDG concepts, how to identify those who understand these concepts and have successfully used them in the past, and how to structure the program to implement these concepts which are being applied in today's competitive global economy. The Manufacturing Development Guide is structured specifically to address these problems. It enables management to identify ahead of time those product and process-related practices that a program should employ to maximize the affordability and performance payoffs and to promote quality. It provides executable guidance in selected functional areas of the acquisition process, program phase by program phase, across the entire acquisition life cycle. For each practice discussed, the MDG offers flexible, specific language for tailoring and insertion into the government's solicitation package, and for incorporation into the contract.

The Manufacturing Development Guide consists of an introduction and six main parts: (1) a discussion of related Acquisition Reform initiatives and their relationship to the MDG; (2) a review of Acquisition Strategy elements which are affected by the MDG implementation; (3) an overview of Manufacturing Engineering's Role in IPPD; (4) MDG considerations in Engineering for Affordability; (5) guidance with respect to quality systems which emphasize defect prevention rather than the traditional inspection philosophy; and (6) a set of 13 MDG practices and their application throughout the acquisition life cycle. Recommended RFP language and Proposal content are provided in chapter 4, Manufacturing Engineering's Role in IPPD; chapter 5, Engineering for Affordability; chapter 6, Quality Systems; and for each of the 13 practices. These practices are briefly summarized in the next few paragraphs and developed in greater detail in Chapters 7, 8, and 9:

1. **Manufacturing Capability Assessment and Risk Reduction** - The manufacturing capability assessment and risk management effort is a structured, disciplined approach to evaluating manufacturing capabilities, identifying and assessing risk, and developing and executing risk mitigation plans in order to maintain an acceptable level of risk throughout an acquisition program. The principle objective is to identify appropriate actions to assure that manufacturing processes are matured along with product design so that they will be available to support the production and support acquisition phase.

2. **Key Suppliers** - Key supplier partnerships and strategic business alliances have become critical factors in today's defense system acquisitions. Partnerships foster joint commitments between companies and promote shared investments in product design and development. Resource sharing and mutually focused internal research and development activities result in aggressive, efficient problem solving and product development. In the Pre-EMD phase, key suppliers should be integrated into proposal preparation activities and become contributing members of Integrated Product Teams as early as possible to take full advantage of their product and process knowledge, and should be selected on a proven ability to perform and on their ability to satisfy program needs. In the EMD phase, contractor partnerships with key suppliers foster joint commitments and promote shared investments in product design and development, resource sharing, and mutually focused risk reduction activities. In Production and Support, long-term partnerships can promote shared investments in product improvement and cost reduction initiatives.

3. **Key Characteristics and Processes** - Key Characteristics are design features for which variation significantly effects product performance, quality, cost, or safety. The identification of key product characteristics and their design limits, and the identification of key production processes and their capabilities, are basic engineering tasks which should be performed in both the pre-EMD and EMD phases to support Integrated Product and Process Development (IPPD), variability reduction, and continuous improvement in the EMD and Production phases, and to facilitate cost-effective product improvement activities. Key Characteristics provide a unique communication tool which links requirements, design, and manufacturing, and support.

4. **Variability Reduction** - Variability reduction is a systematic approach to reducing product and process variability in order to improve cost, schedule and performance. It is based on the concept that just falling within specification limits (goal-posting, pass/fail, attribute testing) is not the best measure of quality. Rather, the degree of variability of a key process and its relationship to design limits (process capability) becomes a measure of merit. The focus of Variability Reduction efforts varies throughout the acquisition process. During Pre-EMD and EMD phases, the foundation for product quality, production capable processes, and continuous product and process improvements are laid through the establishment of data collection and process control procedures and the collection of process capability data for the manufacturing infrastructure. During Pre-EMD and early EMD phases, the type of reports and information needed by the IPTs will be determined. They will provide insight into the manufacturing process capabilities of the prime contractor and suppliers. EMD activities concentrate on implementation of process control procedures for key characteristics and key

production processes. These efforts are essential to assess process capability and stability in preparation for the production decision. Variability reduction efforts during production are primarily concerned with maintaining an environment characterized by continuous improvement in product quality and manufacturing process efficiency.

5. **Virtual Manufacturing** - Virtual Manufacturing is an integrated, synthetic manufacturing approach which effectively addresses the full implications of the materials, processes, tooling, facilities, and personnel issues involved in a new product's design and manufacture *before* the product and process designs are released, and while changes can be inexpensively implemented. A combination of virtual manufacturing and virtual prototyping capabilities enable the IPT to validate product designs and production processes in a synthetic environment, evaluate the performance characteristics of a variety of product configurations, and make truly effective cost and performance trades during early development activities.

6. **Production Cost Modeling** - The intent of this practice is to provide a Production Cost Model (PCM) which can be used to estimate the projected production cost of the proposed design against a threshold value for affordability identified in the System Specification. . In addition, the PCM will be a critical tool in implementing Cost As an Independent Variable (CAIV), and will be used in the trade studies practice to assess and accumulate design related costs (as implemented in the factory) in a statistical manner.

7. **Design Trade Studies** - Design trade studies focus on providing a balanced product design considering cost, schedule, and performance. They should include production process, tooling, test equipment, and support equipment issues. Design trades are guided by a minimal number of system performance parameters. Desired and threshold values are defined for each parameter. Trade studies provide the ability to optimize system design within these values.

8. **Specifications and Standards Management** - The specifications and standards management practice expresses the intent of the government to utilize commercial standards and specifications when they meet military requirements, to tailor out unnecessary requirements, and to emphasize the government's move to a Performance Based Business Environment (PBBE) philosophy. The three part product description, an element of PBBE, is discussed in detail. This concept captures design intent and lays the foundation for significantly lower support costs in the future by facilitating product changes and improvements.

9. **Long Lead and Non-Recurring Activities** - In today's acquisition environment, long lead items and non-recurring activities are issues in the Engineering and Manufacturing Development (EMD) phase of the weapon system program rather than the production phase. One of the key objectives of the new acquisition environment is the incremental demonstration and verification of production process capabilities early on by maximizing the use of final production processes, equipment, tooling, and test equipment in the development phase. This and the relocation of LRIP into EMD requires the program to focus much earlier on many issues that were traditionally part of non-recurring activities in the production phase. Identification of long lead items is usually an early product of the engineering design process. Planning for major infrastructure items such as facilities is initiated in Pre-EMD acquisition phases.

10. **Product and Process Validation** - The focus of Product and Process Validation is on methods of verifying the capabilities of production equipment and processes. The rapid development of effective virtual manufacturing and virtual assembly tools has provided additional methodologies by which many of the objectives of conventional line proofing can be met. The decision to use line proofing, virtual tools, or some combination of the two to support a particular program will require an analysis of the comparative cost, schedule, and quality impacts.

11. **Product Improvement** - Product improvement is a practice used throughout the defense industry which has gained new emphasis in the era of reduced budgets and acquisition reform. Product Improvements are introduced to address new performance requirements or to take advantage of new technologies or subsystems which reduce cost or enhance performance at the same cost. The focus of this practice is use the MDG concepts discussed above, and hopefully applied in the development of the original weapon system, when making product improvements and manufacturing changes. The use of block changes provides a disciplined, cost effective process for introducing and consolidating process changes.

12. **Manufacturing Process Control and Continuous Improvement** - During production, the responsibility of the manufacturing engineering function is to focus on the effective control of the manufacturing processes and on the orderly incorporation of improvements in both product and process. Contracts should be structured to provide incentives for continuous production phase improvements, schedule gains, enhanced affordability, reduced acquisition cost, and enhanced supportability.

13. **Factory Efficiency** - Factory efficiency implies the continuous application during the Production and Product Improvement phase of all appropriate lean manufacturing practices, high performance manufacturing systems, and continuous improvement practices and principals during production. It must also extend far beyond the confines of the factory floor to include such issues as risk management and the long-term impact of make-buy decisions on the industrial base.

CHAPTER 1

1. INTRODUCTION

1.1 The Purpose of the Manufacturing Development Guide

The purpose of the Manufacturing Development Guide (MDG) is to promote the timely development, production, and fielding of affordable and capable weapon systems by including manufacturing and quality considerations throughout the program acquisition cycle**.** Its primary focus is to identify and encourage the use of manufacturing and quality related technical and business practices to achieve this purpose. The MDG emphasizes the role and the responsibilities of manufacturing engineering in all phases of the acquisition process.

MDG provides implementation guidance for Department of Defense (DoD) acquisition policy and is consistent with the Command's Total Quality and Integrated Weapon System Management concept. The MDG promotes Integrated Product and Process Development (IPPD) and concurrent engineering policies, and is in accordance with the change to a performance based acquisition environment; as well as the use of non-government standards, Single Process Initiatives (SPI), commercial products and practices, improved supplier relations, and other acquisition reform initiatives.

This is the first revision to the original MDG, published 30 November, 1993. The original document was created out of a series of government-industry workshops, sponsored by ASC in support of an AFMC initiative to implement Integrated Product Development and Concurrent Engineering. The first edition concentrated on the Engineering and Manufacturing Development (EMD) acquisition phase. This revision expands upon the original by incorporating the latest acquisition reform initiatives and by addressing both pre-EMD (Concept Exploration and Program Definition and Risk Reduction) and Production phases, in addition to updating the EMD information..

1.2 A Statement of the Problem

In the past, the goal of developing and deploying economically supportable weapon systems capable of sustaining all functional user requirements has proven difficult to achieve. Historically two basic problems have been experienced to varying degrees by weapon system acquisition programs: (1) Difficulty in developing, producing, and fielding supportable new weapon systems, modifications, and upgrades in a timely and affordable manner**.** (2) Difficulty in smoothly transitioning an acquisition program from development to production.

1.2.1 The Timely Fielding of Affordable Systems

The defense community’s difficulty in fielding mature systems in a timely and cost effective manner has been a persistent problem experienced to some degree on nearly every program. The symptoms and impacts of these problems vary according to the observer’s perspective, but many of the main issues are summarized below:

Acquisition Community

- **Symptoms:** high risk in the transition from development to production, high initial acquisition costs, and the need for excessive engineering support to stabilize the design and manufacturing processes.

- **Impacts:** increased costs, production schedule slips, and early and frequent engineering changes.

User Community

- **Symptoms:** late deliveries and the inability of the system to meet all requirements, especially in the areas of reliability and supportability.

- **Impacts:** delay in Required Assets Availability (RAA) and reduced operational capability (particularly in sortie generation).

Support Community

- **Symptoms:** high initial repair rates, unexpected failure modes, and excessive configuration changes.

- **Impacts:** increased spares requirements, excessive failure analyses and corrective actions, more complex configuration tracking systems, and numerous technical order changes, resulting in increased costs and the potential inability to maintain adequate operational capabilities.

1.2.2 Transition to Production

Most modern acquisition programs have experienced problems in transitioning from development to production. Symptoms include poor quality and low yields of key manufacturing processes, inability to support production rates using the processes demonstrated in development, and cost increases and schedule delays while production capable processes are being developed. These problems can be linked to (1) the lack of an effective plan for the development and maturity of production processes during the pre-production acquisition phases concurrent with product development; (2) not understanding the linkage between key design requirements, the processes needed to support them, and the impact on product performance, supportability, and cost; (3) ineffective risk assessment, mitigation, and monitoring activities supporting critical process development; and (4) a high risk approach to supplier management via one-way communications, with requirements dictated and passed down through multiple program levels (from the user to the prime contractor and then to suppliers).

1.3 Root Cause

A root cause analysis indicates that a major source of these problems is the lack of stable and capable production processes to support production and operation of the weapon system products. This problem can be characterized as follows:.

Inadequate response to high production risk at the start of the program:

- Lack of balance between product and process development.
- Lack of source selection criteria related to process capability.
- Lack of a long range production investment strategy as part of the overall acquisition strategy.
- Lack of stable requirements, with a reasonable match between requirements and existing production capabilities.
- Lack of programmatic focus on the need for simultaneous product and the process development.

Lack of attention to process capability during development:

- Insufficient or untimely consideration of producibility analyses.
- Product design instability resulting from an emphasis on meeting performance requirements without consideration of producibility.
- Insufficient identification of key product characteristics and key process parameters (product characterization).
- Late initiation of production planning and risk mitigation efforts.
- Lack of exit criteria for key processes and a lack of process related milestones.

Lack of process control in production:

- Lack of process control requirements.
- Lack of identified key product characteristics and/or key process parameters for monitoring and controlling.
- Lack of process improvement efforts.
- Lack of hard cost control requirements or incentives to control / reduce cost.

Lack of emphasis on process capability for field support:

- Failure to consider supportability issues and field environment during design.
- Lack of attention to the maturity and future availability of spare parts.
- Lack of attention to required repair procedures.

- Lack of planning and funding for initial support of the fielded product.

1.4 MDG Success Criteria

To achieve MDG objectives, the following success criteria and supporting practices are stressed.

Achieve a balance in the consideration of product and process capability at the start of every phase of the acquisition process:

- Balanced investments in both product and process during the pre-Production program phases.
- Consideration of process capability in the technology development and technology insertion efforts.
- Incorporation of evaluation criteria for production process capability in source selection with firm requirements for such issues as process development, process validation, process control, and production cost estimation.
- A well-defined production investment strategy as part of the overall acquisition strategy.
- Establishment of capabilities for realistically evaluating the balance of the technical, cost, and schedule aspects of the total system through such techniques as linked cost and performance models and electronic simulation of the manufacturing and support environments.

Achieve a balance of product/process development during each phase of acquisition:

- Identification of exit criteria for all key events and milestones appropriate to developing, establishing, and validating required process capabilities.
- A dedicated effort to stabilize the product design early in the development program through a balanced trade between performance, cost, and schedule, with attention to producibility and supportability.
- Earlier accommodation of production-related issues such as Special Tooling, Special Test Equipment, and Support Equipment (ST/STE/SE) design and fabrication; and use of actual production processes to fabricate, assemble, and test prototype equipment to prove the manufacturing process.
- Modeling and simulation of the design, production, and support environments.

Establish a development and manufacturing environment that implements the practices of key characteristics, process controls, variability reduction, and defect prevention:

- Thorough requirement flowdown practices with identification of key product characteristics, key production processes, and key process parameters implemented at all supplier levels.

- Well-defined process control practices identified in the product specifications and in the build-to data package (which contains all documentation needed to define and build the system, such as drawings, process specifications, and work instructions) as developed by the contractor.

- The implementation of efficient variability reduction programs to improve dimensional control, reduce tolerance stack, yield higher product/process quality and reliability, and institute an environment of preventive rather than corrective action.

Consider field support process capability and environment during product development:

- Development of repair processes during the product development phase.

- Product and process capabilities for spares determined through identification of key product features and process requirements in the build-to package.

- Adequate planning for support of the product starting with initial deployment.

1.5 Manufacturing Development Guide Technical Content

This Manufacturing Development Guide identifies 13 distinct practices to address the success criteria described above. Their application to Pre-EMD, EMD and Production acquisition phases is discussed in Chapters 7, 8 and 9 respectively. Rather than covering all practices in each chapter, only those which are most appropriate for that phase are covered. However, some of the practices are included in more than one chapter. This was done when practice activities and products were dependent on acquisition phase, and to show how their focus and level of detail changes throughout the product development and production process.

In addition to these three chapters, information which is of general interest, and not phase specific, is discussed in Chapters 2, 3, 4, 5, and 6. Each is summarized below:

Chapter 2, Acquisition Reform, provides an introduction to concepts on which MDG practices are supported. Discussion covers acquisition reform initiatives such as Team Work, Integrated Product and Process Development, the Performance Based Business Environment Cost as an Independent Variable, the Single Process Initiative, and Specifications and Standards.

Chapter 3, Acquisition Strategy, addresses business strategy issues such as program and financial management, program scheduling, cost reporting, and funding requirements necessary to implement the MDG practices. It also contains a special section addressing the Statement of Objective (SOO) Philosophy in program acquisition.

Chapter 4, Manufacturing Engineering's Role in IPPD, overviews the heightened importance of the manufacturing engineer's mission in the integrated product environment. The involvement of manufacturing engineering in this product definition process provides for early identification and mitigation of producibility issues, cost issues, and potential transition-to-production risks.

Chapter 5, Engineering for Affordability, addresses weapon system costs, both flyaway and life cycle, and the need for these costs to be treated as system requirements which are equal in importance with quality, reliability, and technical performance. It is essential that product cost be a consideration in early design trade studies and that reliable production cost models be developed to support these technical trades as well as assessing the impact of changes on the program cost. Cost partitioning, design-to-cost, "lean" manufacturing, and "design for x" (i.e., design for manufacturability, assembly, and so forth) are examples of practices which support engineering for affordability. Special consideration should be given to costs associated with the environmental impact of materials and processes used in the weapon system across the system life cycle--from initial manufacture to disposal. These costs are often "hidden" in the sense that they are not known to the engineering development staff or not accounted for in the engineering trades process.

Chapter 6, Quality Systems, addresses the correlation between the tools and techniques contained throughout this guide and concepts that many companies have implemented as part of their modern Quality Systems. Both emphasize the importance of quality in the development process to achieve producible designs; quality in the design of capable, controlled manufacturing processes; and quality through the prevention of defects rather than after-the-fact detection of defects.

1.6 Intended Use of MDG

The objective of this document is to provide a technical understanding of these practices, guidance on how to include these concepts in the RFP and contract, and guidance on how to assess the success of their implementation throughout the acquisition process. To this end, recommended RFP/contract information is provided for each practice and includes example content for the Statement of Work (SOW), Integrated Master Plan (IMP) exit criteria, Contract Data Requirements List (CDRL), Proposal Instructions to Offerors (Section L), and Evaluation Criteria Guidance (Section M). In addition, sample Statement of Objective (SOO) language is provided in the introductions of the acquisition phase chapters and in the Quality System section, Chapter 6, to convey the government's expectations for manufacturing and quality during the acquisition process. Finally, the MDG recommends that Average Unit Production Price (AUPP) be included in the System Specification to emphasize affordability and the concept of Cost As an Independent Variable (CAIV). To this end, example specification language is included in the EMD Production Cost Model practice, Chapter 7.

1.7 The Relationships Between Practices

Figure 1-1 provides a visual map of all the practices and indicates the flow of relationships back and forth between practices. For instance, the Key Characteristics, Variability Reduction, and Manufacturing Capability Assessment and Risk Reduction practices are intimately related

both within the acquisition phase and across acquisition phases. Each of these practices relies on input from the others to achieve its full potential for return on investment. In another example, the Production Cost Modeling practice in EMD can benefit greatly from well-executed practices covered in the MDG sections on Manufacturing Engineering's Role in IPPD, Engineering for Affordability, and Virtual Manufacturing during pre-EMD activities. Figure 1-2 provides another perspective on the interrelationships between MDG practices. This matrix representation shows both the relationships between each practice and the other practices within the program phase, and the relationships between each practice and those practices in the preceding and following program phases. This matrix also shows both primary or driving relationships and secondary relationships.

The MDG objective is the implementation of all the practices in an Integrated Product Team environment with all stakeholders involved. These practices are much less effective if implemented in a discrete or sequential fashion.

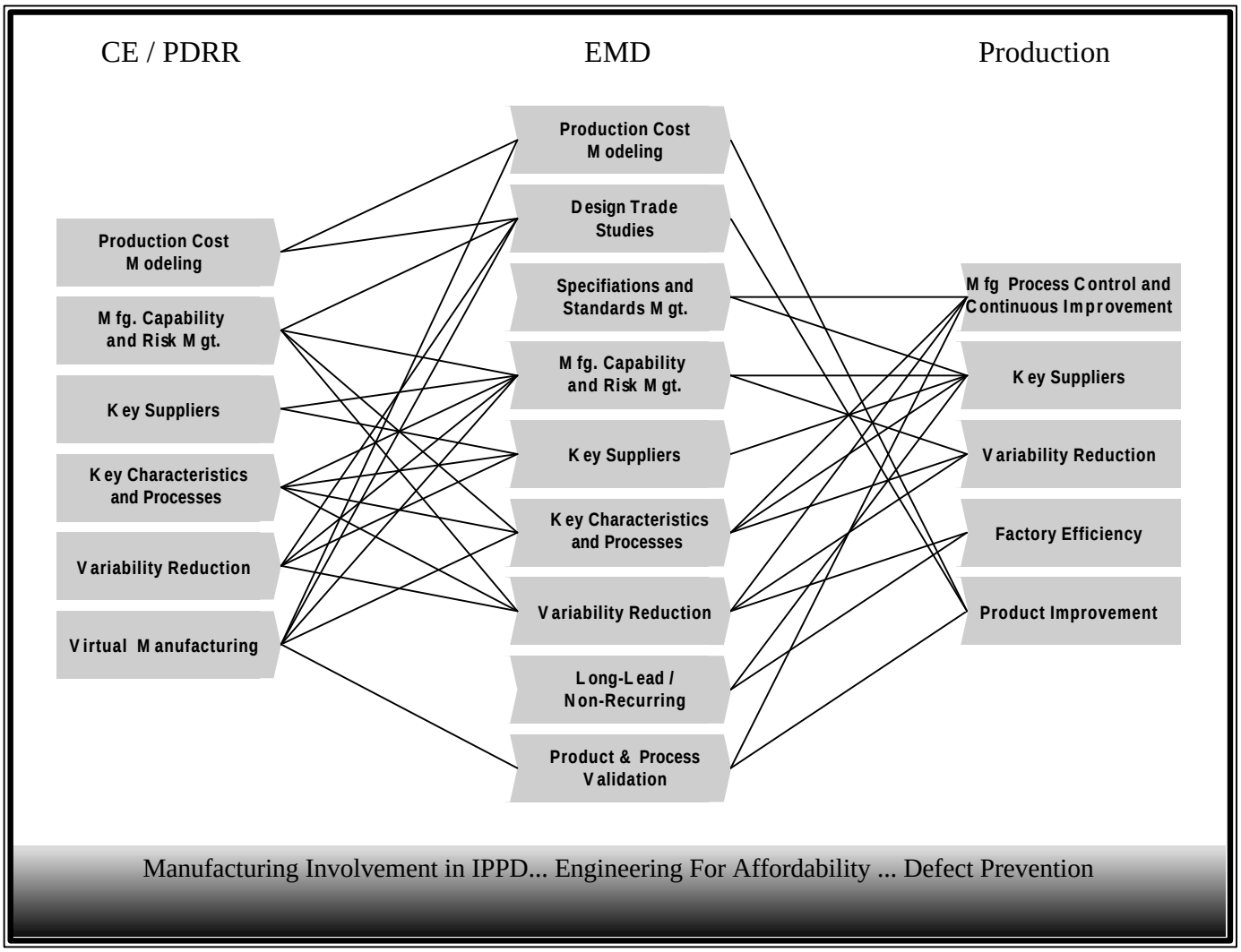

Figure 1-1. MDG Practices Are Integrated Across Program Phases

Relationships P - Primary S - Secondary		PCM	Mfg. Cap. & Risk Mgt	Key Suppliers	Key Char. & Proc.	VR	Virtrual Mfg.	PCM	Design Trade Studies	Spec. & Std. Mgt.	Mfg. Cap. & Risk Mgt.	Key Suppliers	Key Char. & Proc.	VR	Long-lead/Non-Rec	Prod. & Proc. Val.	Mfg. Proc. Cntl.	Key Suppliers	VR	Factory Efficiency	Product Improvement
Pre-EMD	Production Cost Modeling		S					P	P	S											
	Mfg Capability & Risk Mgt			S	P	P	P		S		P	S	P	P		S					
	Key Suppliers				S	S			S		P	P	S	S	S						
	Key Char & Processes					P			S	P		P	P	P	S	S					
	Variability Reduction						S		S		P	P	S	P		S					
	Virtual Manufacturing							S			P		P	S		P					
EMD	Production Cost Modeling								P	S	S				S		S			S	P
	Design Trade Studies										S	S	S	S	P						P
	Spec. & Std. Mgt.										P						P				
	Mfg. Capability & Risk Mgt.											P	P			S	S	P	P		S
	Key suppliers													S	S			P	S		
	Key Char. & Processes													P		S	P	P	P		S
	Variability Reduction															S	P		P	P	
	Long-Lead/Non-Recurring																	P		P	
	Product & Process Val.																P				P
Production	Mfg. Proc. Cntl & Imp																	P	P		S
	Key Suppliers																		S		
	Variability Reduction																			P	
	Factory Efficiency																				S
	Product Improvement																				

Figure 1-2. The Impact of Implementing MDG Practices and Principles

Implementing MDG practices and principles, like many other aspects of acquisition reform, represents a significant change in the way the defense industry operates. Achieving the full range of benefits available through the MDG practices will require basic cultural changes on the part of all parties involved, from users through low-tier suppliers. Some of the practices will require an up-front investment of material and/or labor during early development, with returns not realized until late in EMD or Production. The commitment to make these up-front investments and maintain the MDG practice activities throughout the life of the program is essential. The benefits of implementing MDG practices include:

- Shorter development schedules and reduced cycle times.
- Better first article quality.
- Development of robust product designs.
- Easier transition of designs to production.
- Better supplier product integration.
- Quicker resolution of problems.

- More effective risk management.

2. ACQUISITION REFORM

2.1 Introduction

The Department of Defense (DoD) 5000 Series consists of two documents (DoD 5000.1 and DoD 5000.2-R) that establish policies, principles and mandatory procedures for the acquisition of major defense and major automated information systems. In 1994, the Office of the Secretary of Defense recognized the need for fundamental changes in the DoD 5000 Series to incorporate new laws, policies and procedures and most importantly, to set the stage for a cultural change in the way the defense acquisition community, including industry, does business by institutionalizing acquisition reform, Integrated Product and Process Development, and use of the integrated product teams (IPTs). These changes are oriented toward smoothly acquiring superior military systems, with reduced cycle time and at an affordable price.

With recent DoD directives in place, most of the proscriptive specifications and standards that have governed procurement practices for the past several decades are gone. The acquisition community is now working with performance based specifications and standards, non-governmental and commercial standards, single process initiatives and block contract changes, and a number of other tools and initiatives which have been shown to impact affordability metrics favorably. While MDG is not an acquisition reform initiative, it is consistent with current directives and supports their objectives.

2.2 Features of Acquisition Reform

Just as the quality revolution changed the consumer market place, acquisition reform is changing the defense marketplace. Major features of this environment which relate to the MDG include:

- A new emphasis on system affordability and the acquisition of the best value product.
- Performance based requirements and specifications that are incrementally verified throughout development.
- A formal program of risk identification and management in the areas of performance, affordability, and schedule.
- A disciplined systems engineering approach for development, design, and fabrication documentation at all levels of the requirements allocation hierarchy.
- Contractor control of the development, design, and configuration to the maximum extent feasible.
- The maximum use of contractor processes and facilities.
- Enhanced opportunities for the incorporation of advanced technologies.

- Expanded use of modeling and simulation for both product performance and product manufacturing.

- Transitioning from an emphasis on government oversight to government insight.

2.3 Essential Conditions for MDG Success

For the full benefits of MDG to be realized, the following features of the acquisition environment must be present:

- Implementation flexibility is critical if the increased contractor and government efficiencies available through performance based acquisition are to be realized.

- Performance based specifications must incorporate the essential performance attributes formerly contained in documents such as the Statement of Work (SOW) and MIL Standards and Specifications.

- A common technical database must support all system design, fabrication, and support requirements, including engineering design, tooling, test and support equipment, and technical orders.

- Effective flowdown of PBBE requirements and principles to the lowest level of the supplier chain is essential to permit intelligent, flexible tailoring of the requirements, and to allow suppliers to use their processes effectively so that product integrity is assured.

- A performance based product description data package must capture not only the development specification and build-to information, but design intent and requirements allocations as well.

2.4 Acquisition Reform Initiatives Supporting MDG

Acquisition Reform and the DoD 5000 series documents cover all functional aspects of the acquisition process, while the MDG focuses on manufacturing and industrial engineering practices supporting the development and production of a weapon system. While not an acquisition reform initiative, MDG does support acquisition reform. Discussed below are several acquisition reform initiatives which relate to and support MDG practices and guidance.

2.4.1 Teamwork

One of the major goals of the MDG (and acquisition reform in general) is to make the government an active participant in the prime contractor's day-to-day program activities through membership on the contractor's Integrated Product Teams. One direct benefit of this increased government participation is that it serves to minimize the number of formal Contract Data Requirements and reviews. The paradigm is government management of the program through insight into the daily activities of the program instead of through oversight via formal reviews and

deliverables. The following subsections briefly look at several key elements of the PBBE environment.

2.4.2 Integrated Product and Process Development

Integrated Product and Process Development (IPPD) and Integrated Product Teams (IPTs) represent a cultural foundation which is essential for successful implementation of the practices described in the Manufacturing Development Guide. IPPD is DoD terminology for the implementation of concurrent engineering methods. In the AFMC Guide on Integrated Product and Process Development, IPPD is defined as a philosophy that systematically employs a teaming of functional disciplines to integrate and concurrently apply all necessary processes to produce a product that satisfies customer needs. IPTs, in turn, represent a management approach for accomplishing IPPD. An IPT is a team formed for the purpose of delivering a specific product or managing a specific process. IPTs bring together all the functions that have a stake in the performance of the product or process. The members of the IPT concurrently consider all issues affecting the design, development, and production of the product.

2.4.3 Cost as an Independent Variable

Another key consideration of the performance based business environment is the issue of Cost as an Independent Variable (CAIV). In a CAIV Working Group Report issued December 21, 1995, CAIV is identified as a major theme of the DoD 5000.1 and DoD 5000.2R series. The acquisition process "must consider both performance requirements and fiscal constraints," the report says, and stipulates that cost should be "an independent variable in programmatic decisions, with responsible cost objectives set for each program phase." CAIV, in other words, is intended to focus acquisition efforts much more rigorously on tradeoffs between cost and the desired features and performance characteristics of the weapon system. One result is that cost estimating tools will need to be used early on, in the conceptual phase of a program.

In an analysis of CAIV issues presented to the American Society of Naval Engineers[1], the impact of CAIV is assessed as a fundamental one. The need to make cost a higher priority will necessitate a shift from the traditional requirement setting process, and will necessitate some important procedural changes in cost estimating, the report concludes. These procedural changes will include a streamlining of the mechanism of costing, a shift in the choice of variables, a mathematical reversal of the process, and better top-level descriptive equations and graphics that portray total costs as a function of operational and technical parameters.

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[1] *Cost as an Independent Variable (CAIV): A Framework and a Tool Set for Costing in a CAIV Environment,* Richard L. Coleman, TASC, Inc., and Dineen O. Manarelli, OUSD (A&T), S&TS, NW. (A 1996 paper submitted to the American Society of Naval Engineers.)

2.4.4 Single Process Initiative (SPI)

The Single Process Initiative seeks to change existing contract-specific processes to common, facility-wide processes to achieve long term cost reductions for both the government and contractor. Use of common processes is intended to reduce contractor operating costs and achieve cost, schedule, and performance benefits for the government.

The initiative provides for the transition of contractor facilities from detailed government specifications and standards to the use of common, facility-wide processes on existing contracts. The ACOs will take the lead to coordinate and negotiate class contract modifications (Block Changes) to existing contracts for contractor single process proposals. It is up to the contractor to propose scope and technically substantiate common process proposals.

There is high expectation and potential for significant cost savings in the future through streamlined and more efficient common processes in contractor facilities. It requires a streamlined approach to implement this initiative quickly so the Air Force can begin to see the savings and cost avoidance associated with common facility wide processes.

2.4.5 Specifications and Standards

To meet future needs, the Department of Defense must increase access to commercial state-of-the-art technology and must facilitate the adoption by its suppliers of business processes characteristic of world class suppliers. In addition, integration of commercial and military development and manufacturing facilitates the development of dual-use processes and products and contributes to an expanded industrial base that is capable of meeting defense needs at lower costs.

To accomplish this objective, the Deputy Under Secretary of Defense (Acquisition Reform) directed the use of performance and commercial specifications and standards in lieu of military specifications and standards unless no practical alternative exists to meet the user's needs. Performance specifications communicate the user’s requirements to the supplier. They translate operational requirements into more technical language that provides the manufacturer with two very important parameters: (1) What to consider as an acceptable product--stated in product performance terms, and (2) How the government will determine if the product is acceptable.

The following is the preferred specification use:

a. **Primary Preference for Use of Performance Specifications**. Performance specifications shall be used when purchasing new systems, major modifications, upgrades to current systems, and nondevelopmental and commercial items, for programs in any acquisition (ACAT) category. Major modifications and upgrades are as defined in DoDR 5000.2. Five types of performance specifications have been identified: non-government standards, commercial item descriptions, standard performance descriptions, guide specifications, and program unique specifications.

b. **Secondary Preference for Non-Government Standards**. If it is not practicable to use a performance specification, a non-government standard shall be used.

c. **General Preference for Use of Open System Specifications and Standards (Requirements for Standard Architectures and/or Interfaces) for Acquisition of Weapon System Electronics**. "Open systems" specifications and standards (electrical, mechanical, thermal) will be used for the acquisition of weapon systems electronics to the greatest extent practical. Open system specifications and standards are consensus-based public or nonproprietary specifications and standards for systems and interfaces of hardware, software, tools, and architecture. These systems and subsystems shall be designed, developed, and constructed as open systems during the acquisition and modification process to reduce life-cycle cost and to facilitate effective weapon system intraoperability and interoperability. Open system specifications and standards can also have characteristics which define them as other document categories, such as non-government standards and interface standards.

2.4.6 Supplier Relations

Another key focus of MDG is the relationship between the prime contractor and suppliers. In this context, suppliers include:

- Subcontractors directly subordinate to the prime contractor through contractual ties.
- Government Furnished Property (GFP) contractors managed by the government but supplying materials, components, assemblies, or subassemblies to the prime contractor.
- Government agencies directly supporting the prime contractor's efforts.
- The prime contractor’s own in-house work centers.

Key Lower-Tier Suppliers

It is essential that the prime contractor have real insight into the activities of all suppliers and integrate these activities into the weapon system planning processes. In the past, many subcontracts were conducted as "arm's length" arrangements with minimal technical interchange and even less management oversight. This kind of arrangement may still be practical for low risk, non-complex items and materials, but is not suitable for complex items which require significant integration, or which could introduce significant risk to the program.

Specific interfaces between the prime and the supplier should be directly related to the risk associated with use of the supplier's product. Where it may be necessary, or advantageous, to use GFP contractors or to provide material directly to the prime, the government must ensure that the appropriate Associate Contractor Agreements exist to allow the prime contractor efficient access to GFP program information. This access must be at a sufficient level of detail and on a timely enough basis to allow the prime to assess and manage potential impacts to the weapon system program.

Open Systems Architecture

A major acquisition reform initiative which affects all DoD acquisition and sustainment managers is known as "Open Systems." This initiative, which is also oriented toward furthering the goals set out in the SecDef military specifications and standards policy, was established in a November 1994 OUSD(A&T) memorandum. In that memorandum, OUSD(A&T) directed "...that 'open systems' specifications and standards be used for acquisition of weapon systems electronics to the greatest extent practical." To sponsor and accelerate adoption of open systems in weapons systems acquisitions, OUSD(A&T) set up an Open Systems Joint Task Force (OS-JTF). The OS-JTF initially focused on electronics, since this "domain" represents an ever increasing weapon system cost driver. This focus was later expanded to encompass other "domains" such as mechanical systems, management information systems, and support systems.

This initiative recognizes that in today's global economy, everyone, including our potential adversaries, will gain increasing access to the same commercial technology base. The military advantage in this environment will go to the nation which is able to substantially reduce the cost and cycle time associated with capturing advanced technologies, incorporating them into weapon systems, and fielding new operational capabilities. In addition, the ability to quickly and efficiently upgrade and modify these weapon systems with evolving technologies will be critical due to the rapid technological change rate which makes today's most advanced capabilities quickly obsolete.

Open Systems (OS) concepts and architectures permit efficient advanced technology integration into new weapon systems, as well as preserve the ability to accomplish new technology insertions at minimal cost later in the system's life. This latter aspect is crucial. With steadily declining budgets since the end of the Cold War, the military market represents only a small fraction of a dominant commercial business sector, especially in the electronics area. It is this commercial market which is now driving technological advances. As a result, commercial product use will in many cases represent the only viable solution from a cost, performance, and availability standpoint. Even in those cases where a unique military technology or standard is necessary to meet warfighter requirements, OS approaches will facilitate faster and more economical acquisition, modification, and sustainment processes. As provided for in the OUSD memorandum, OS concepts must be incorporated into every phase of the acquisition process and supported at all DoD management levels.

2.4.7 Performance Based Business Environment (PBBE)

The Joint Aeronautical Commanders Group (JACG), which was formed by the Joint Logistics Command and is led by the ASC Commander, coined the term PBBE. This concept defines an environment which implements the objectives of acquisition reform and provides guidance on the acquisition of aeronautical weapon systems. PBBE products include documents covering risk management, flexible sustainment, performance-based product definition, joint service guide specifications, key supplier processes, and contractor performance. These documents, as well as other JACG information, can be reviewed through the Internet on the ASC/AZ Web page: http:/www.wpafb.af.mil/az/jacg/pbbe/pbbe.htm. Manufacturing and quality personnel should become familiar with PBBE concepts and consider them in conjunction with MDG practices when supporting acquisitions at Aeronautical Systems Center.

3. ACQUISITION STRATEGY

3.1 Introduction

An acquisition strategy should be developed for every acquisition program to serve as a road map for the execution of the program. It should cover a variety of programmatic, financial, and contractual issues.

As discussed in the preceding section on Acquisition Reform, DoD Regulation 5000.2 stresses the need for treating product producibility and production cost as high priorities. The MDG production engineering and producibility efforts start at Milestone I and continue through the Production phase and extend even into product support. The focus of these efforts is on simplifying the design and stabilizing the manufacturing process in order to reduce manufacturing cost, lead time, and cycle times. The selection of manufacturing methods and processes becomes, in effect, a design function.

Consistent with the guidance in DoD Regulation 5000.2, the MDG approach moves tasks such as production tooling, planning, and process development forward into the Program Definition and Risk Reduction (PDRR) and Engineering and Manufacturing Development (EMD) phases. MDG supports this approach by more completely defining the production article and its manufacturing quality requirements in the earlier program phases. The traditional funding profile must likewise shift, pulling some traditional Production phase funding into EMD and pre-EMD phases.

3.2 Program Management Considerations

This section of the Manufacturing Development Guide provides information on the proper management structures for implementing a program's manufacturing and quality technical requirements. Included are guidelines on developing viable program schedules, minimizing contractual calendar milestones, getting user commitment on production quantities, and effecting RFP process changes. Also discussed are a variety of contracting and source selection issues.

3.2.1 Schedule Development Activities.

Development of an integrated program schedule is the responsibility of the contract program manager. Traditionally, schedule development activities have begun well before the Draft RFP is released, and continue throughout the program's life. The form of these schedules may change, but fundamentally they identify tasks to be accomplished, the interdependencies of tasks and their linkage to milestones, and a calendar association for each task showing its start and completion. In today's environment, this schedule take the form of the Integrated Master Plan (IMP) and Integrated Master Schedule (IMS).

Integrated Master Plan (IMP) - The IMP is an event-driven plan that documents the significant accomplishments necessary to complete the work defined in the SOW and ties the accomplishment to a key program event.

Integrated Master Schedule (IMS) - The IMS provides a schedule to complete the accomplishments defined in the IMP, and may also provide more detail and insight into the completion of an accomplishment.

IMP/IMS will integrate all of the unique aspects of the program and serve as a single management tool to monitor progression toward the accomplishment of program goals and objectives. Therefore it is critical that MDG tasks be identified in the IMP, along with exit criteria which define successful completion of the task. The IMP then relates these MDG activities to program milestones and schedules. This is of particular importance because of the increase in technical requirements in support of MDG. An increased emphasis on schedule development is required to effectively implement MDG, and must begin well before the DRFP phase begins.

The initial schedule must be developed by the program IPT. Typically, the schedule is developed by the SPO's program control personnel in conjunction with the other functions. Once the initial schedule has been developed, it should be modified to reflect the inputs of prospective contractors, solicited during the draft RFP stage. The goal is to develop an integrated schedule that considers all contractor inputs. Updates can be made during source selection.

At source selection, the RFP should ensure that adequate data is requested to accomplish a Schedule Risk Assessment (SRA) for each offeror. An SRA will be conducted on each offeror's proposed schedule at source selection. The SRA will incorporate all of the contractor's proposed changes to the program schedule (which are usually minimal) and will also incorporate the risks inherent in each proposal.

Once the winning contractor has been selected, the schedule can be monitored by the appropriate IPT personnel. Periodic SRAs are recommended to determine current schedule status and identify needed updates.

3.2.2 Minimizing Contractual Calendar Milestones

To ensure that the proper contractual structure exists for effective implementation of MDG, the program manager should establish only the minimal contract milestones necessary to manage manufacturing risks. One example of an appropriate milestone, for instance, might be the criteria for process verification as part of System Verification Review. The movement toward minimization of milestones is a function of several related developments: acquisition reform and the emphasis on integrated product teams, the new partnership relationship between the contractor and government, and the reduced delivery of official data items. As a partner in the development process, program office personnel will have insight into development activities, data, and status. The milestones of the past are now accomplished incrementally, in an ongoing process, and through direct knowledge of development activities. This reduces emphasis on formal reviews, approvals, and contract changes, along with the administrative overhead associated with these actions. In addition, it ensures that contractual milestone adjustments and formal contract changes resulting from a dynamic development environment are minimized.

3.2.3 Production Rates and Quantity Ranges.

Another key element of integrated process and product development is the understanding of the rates to be achieved during production. Production rates will help in determining the type of process to be used. Different processes are more efficient at different production rates. The process that is most efficient at a rate of 100 units a year may not efficient at rates of 10 a year or 1,000 a year. It is therefore vital that the government recognize that a variety of key program estimates and assumptions (as well as tradeoffs and production cost models) are based on a specified production quantity that seems achievable and sustainable. While it is out of the program manager's control to influence Congressional action on quantities, an up-front commitment to a planning quantity is necessary. Since Congress and threat changes may influence quantities, perhaps the best commitment to gain is to a range of quantities. This range is just as important as a point estimate of the quantities per year. In the RFP, therefore, the offerors should propose to a specific quantity, with explanations of how their proposal would change with changes to the proposed quantity. (See the sections on Engineering for Affordability and Production Cost Requirements elsewhere in this guide.)

3.2.4 Cost Reporting Considerations.

DoDD 5000.1 and DoDR 5000.2 still require appropriate management control and cost reporting systems. The purpose of these systems is to provide contractor and government Program Managers with accurate data to monitor execution of their program and provide an adequate basis for responsible decision making . The government should not impose a specific cost and schedule management control system on the contractor. The prime contractor now has a great deal more flexibility in cost reporting. In effect, contractors can now structure the work breakdown to fit their own accounting systems and collect and report costs by task. The system must (1) indicate work progress, (2) properly relate cost, schedule, and technical accomplishment, (3) be valid, timely, and able to be audited, and (4) provide the DoD program manager with information at a practical level of summarization. Level and frequency of reporting should be tailored for the specific program to meet the government's insight and periodic reporting requirements, and should be based on such things as risk, high value, or high technological interest areas. Tailoring the cost reporting system requirements to meet insight requirements is key to achieving a cost effective reporting system.

3.2.5 Technical Data Package

In the Performance Based Business Environment (see Section 2.4.7), the technical data package is actually a three-part performance based product description developed by the contractor. Part 1, the *product development definition*, is similar to the traditional development specification. It links the operational and engineering environments, establishes the performance requirements to be met by the design effort, and translates them into technical performance language. Part 2, the *product design definition*, represents a significant departure from traditional DoD practice. Consistent with modern commercial quality practices, it defines key product characteristics, product acceptance criteria, and interface characteristics. Part 3, the *product fabrication definition*, provides a product build package with detailed drawings, bills of material, and production processes requirements and standards.

Decisions on who controls which portions of the technical data package at each level of the specification tree must be driven by program and technical risk, contractor and subcontractor capabilities, affordability issues, and business strategies. Contractors exhibiting greater capabilities for self-governance will be allowed greater authority and responsibility.

3.2.6 Non-Developmental or Commercial Products

While the main focus of MDG is on development issues, the use of non-developmental items (NDI) or commercial off-the-shelf (COTS) products and processes will certainly increase in the lean acquisition environment. Appropriate processes will therefore need to be developed to assure the effective integration of these products into programs, and to assure their availability, performance, supportability, and cost effectiveness. With respect to cost, the best projections indicate that the judicious use of COTS products will serve to reduce program costs. Acquiring components for systems from commercial vendors can provide cost, schedule, and technical benefits alike.

3.3 Financial Considerations

Two financial issues are associated with implementation of the approaches recommended in this guide. The first is a change in development funding profiles to support doing the right tasks at the right times. The second is recognizing the favorable impact that well-timed applications of these techniques will have on reducing the costs of design iterations in the later stages of EMD and ultimately reducing unit production cost. These considerations are reflected in different ways in each phase of a program, as described in the following subsections.

3.3.1 Funding Requirements for Pre-EMD, EMD, and Production

Perhaps the most important business issue related to the implementation of MDG is how to properly fund programs with these new requirements. In practice, the implementation of MDG will produce significantly different funding profiles than those experienced on past programs, as Figure 3-1 illustrates. (To provide an accurate comparison, the projection in the figure assumes that LRIP is conducted in EMD for both funding curves. In actuality, the MDG approach moves LRIP into EMD for new programs; in traditional programs LRIP occurs in Production.)

In comparison to historical programs, for example, those programs which incorporate MDG principles may require earlier funding, but the benefits of this earlier investment will greatly reduce life cycle costs, including non-recurring production costs, through the substantial elimination of errors and change orders later in the program.

Since MDG suggests, in accordance with DODR 5000.2, that manufacturing processes be proven prior to the start of production and that there be early involvement of the manufacturing engineering discipline in the design process, inefficiencies in the manufacture of initial production units promise to be fewer and the producibility of the initial design should be improved over that of historical programs. A number of other factors associated with MDG-influenced EMD activity will create a more efficient production environment, reduce the cost of the first production unit, lower the cost improvement curve, and shorten the time required to reach the standard hour

content. Taken together, these kinds of production efficiencies clearly will more than offset any additional early development costs. We may not, however, have to wait that long to earn a return on our MDG investment. It has been demonstrated in a recent MANTECH-sponsored study that MDG investments in the early design phases can and likely will lead to increased efficiencies and cost reductions during the later design phases (i.e., fewer producibility design changes, reduced process and line-proofing, etc.). It is possible, as illustrated in Figure 3-1, that cost reductions will provide enough payback to recoup MDG investments even before the full-rate production phase begins.

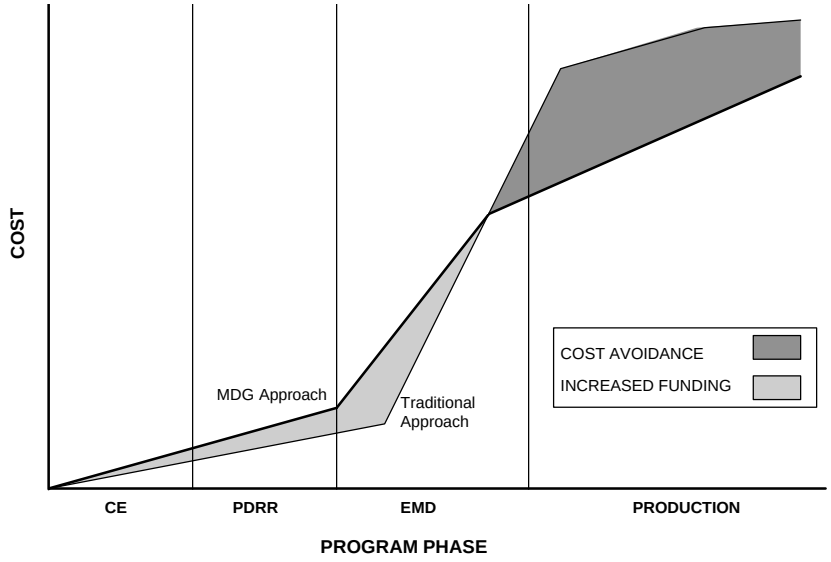


Figure 3-1. A Comparison of MDG and Traditional Program Funding Profiles

3.3.2 The Impact of MDG on the EMD Funding Profile

An example of the impact of implementing MDG practices on program funding profiles during EMD is shown in Figure 3-2. The figure displays the percentage of funds expended for major EMD milestones (PDR, CDR, First Flight), at 12 and 24 months after the First Flight, and at EMD completion. The lower curve in this figure (labeled "Traditional") represents the average EMD expenditure profile for four historical programs: F-14, F-15, F-16, and F-18A/B. As the figure shows, at first flight these programs had, on average, expended about 50% of their development funding.

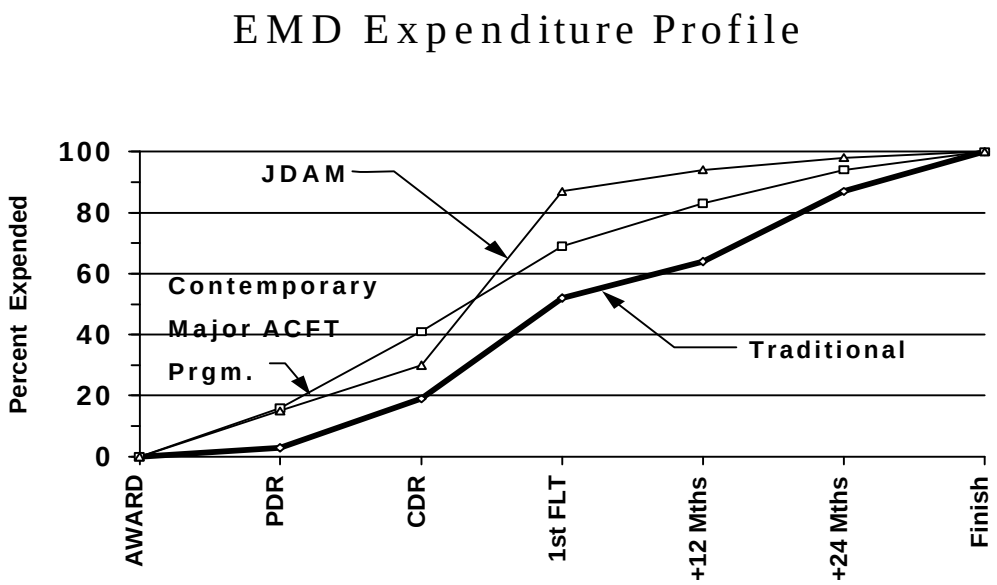


Figure 3-2. EMD Funding Profile Comparisons

For comparison purposes the expenditure profiles for two current programs, F-22 and JDAM, are shown. These programs represent both ends of the acquisition spectrum, from a large, high technology aircraft development program to a multi-service munitions effort. Both of these programs were in EMD during the Fall of 1996, JDAM near completion and F-22 just prior to first flight. The curves are based on actual expenditures through October 1996 and projections for the remainder of the EMD effort. Both of these programs have been affected by acquisition reform and have implemented many MDG concepts and practices: Integrated Product and Process Development (IPPD) and concurrent engineering principals; better integration of suppliers earlier in the development process; Key Characteristics, and Variability Reduction. The expenditure curves illustrate that the MDG concepts have started to significantly affect the phasing of EMD funds. Approximately 70 to 85% of EMD funding has been expended by first flight, compared to the 50% for the historical programs.

This reflects implementation of MDG approaches and requires that efforts usually accomplished late in EMD be moved forward. Certain production phase efforts such as Low Rate Initial Production (LRIP) experience must also be accomplished during EMD. The expenditure profile on the current programs is thus more front-end loaded. Although a single contract may be used for both development and for long lead/non-recurring production items, different types of funding will still be used for each (that is, development funding and production funding). Currently there is no expectation of a change in policy to allow a single funding type to cover both LRIP and the basic EMD requirements.

3.3.3 MDG Cost Estimating Considerations

Pre-EMD Phase - Cost estimating considerations for pre-EMD activities center on the participation of Manufacturing Engineering and Quality Engineering in the IPTs in order to provide the requirements/cost/ producibility trades which are essential to the new acquisition process. The result is a new set of scope of work issues as measured against traditional program profiles. The typically modest cost of this new scope is offset by reductions in total design cycle time and the enhanced productivity of the new engineering analysis tools. One defense contractor cites a rule of thumb in which one production operations person per ten design engineers is added to accommodate the new scope of work, with savings more than recouped later. The intent is that the pre-EMD effort produce prototypes with product design features that are economically producible. The prototype then becomes the baseline, with incremental verifications and validations of the design provided by pre-EMD modeling and simulations.

EMD Phase - Cost estimating considerations for the EMD phase must now consider the effects of the movement of traditional LRIP activities to EMD and the additional activity required in EMD. MDG promotes a number of acquisition approaches which require greater effort up front. It can be assumed that EMD will shift labor hours in engineering and tooling to an earlier point in the program as we integrate the design and manufacturing efforts earlier in the program. Leading defense contractors are reporting that design changes can often be reduced by 50% or more. On the F-15 program, for instance, MDG-related changes would have reduced tooling costs by 40%.

MDG also recommends the involvement of suppliers early in the design process. It is probable that this requirement will necessitate additional costs in the Material/Subcontract area in EMD. While the total number of suppliers will not increase, the amount of their non-recurring cost will, since they will be brought into the program team to assist in the design phase. The amount of this increase would depend on the number of suppliers involved and how early in the process their involvement begins. We should also expect supplier related design changes to decrease (with a corresponding decrease in costs) because of earlier supplier involvement in the design process.

Product and process validation (see Chapter 8, Section 8.10) is another concept advocated by MDG. In the past, if done at all, conventional line proofing most often occurred in LRIP. Under MDG, it would ideally take place in EMD, since LRIP experience must be acquired in EMD as required by DODR 5000.2. However, the ability to detect product design errors and tooling errors in a virtual environment in the pre-EMD phases as well as EMD (and the process of incremental verification and validation) will reduce the necessity for or the extent of conventional line proofing needed, and reduce the need for correction of errors in released design packages, including SE/STE.

The extent of cost changes in EMD is dependent on the amount of MDG related effort incorporated into each program. Since the technical requirements can be tailored, each program should have content differences. The cost analyst or estimator should consult with the IPT to ascertain the extent of MDG compliance. However, it is anticipated that EMD would be the cost break-even point for programs aggressively applying MDG tools and practices.

Production Phase - Production phase costs and cost estimating will also be affected by the MDG initiatives. The MDG-influenced up-front investment in EMD concepts should produce a cost payoff in Production. (Initial cost projections on the JSF Technology Demonstration Program showed unit production cost avoidance due to MDG to be 20% to 30% of the affected hardware budget. Since some traditional LRIP activities will now be accomplished in EMD, production costs must also be adjusted appropriately.

Contractors are now experiencing significant decreases in costs on first units of redesigned product where the IPT processes and virtual manufacturing approaches have been employed. Specific areas of increased production efficiency which can be expected from the use of MDG strategies are described in the following paragraphs.

First, redesign of the system should be significantly reduced. Traditionally, systems and processes have been designed in EMD, with changes then made late in EMD and early in production. This design rework, commonly designated in historical cost data as recurring and non-recurring production engineering (rather than systems engineering) and tooling, should be significantly reduced. In many cases this is due directly to the efforts of the production operations members of the IPT.

Second, with the design and manufacturing processes better integrated with manufacturing, the amount of scrap, rework, and repair traditionally associated with manufacturing will be reduced.

Third, since major subcontractors have been involved in the design process, integration of their components into the system should be more efficient. This should be reflected in labor hour savings for all major functional disciplines and more beneficial cost improvement curves. It should also be reflected in fewer engineering changes related to supplier activity.

Fourth, manufacturing labor should start at a lower first unit or T_1 cost and proceed down a cost improvement curve which parallels and is below the historical non-MDG curve. Better integration of the design and manufacturing process should bring about a less costly first unit. Traditionally, first unit costs have been high because of the significant amount of manufacturing and re-manufacturing needed to incorporate producibility design changes. This, coupled with the inefficiency of incorporating these changes late in the process, caused high T_1 costs and steep cost improvement curves. MDG should create lower first unit production costs and improve efficiency by moving both prime contractor and subcontractor labor to a flatter portion of the cost curve.

Figures 3-3 and 3-4 provide projections of the impact of advanced new design and analysis tools and new manufacturing engineering processes (specifically, virtual prototyping) in an IPPD environment. Both staffing profiles and unit cost curves exhibit significant savings and shortened development cycle times over earlier programs. (The learning curve slope in combination with the lower initial unit cost is based on actual defense contractor experience.)

Fifth, the performance based approach to acquisition provides significant savings in the development and maintenance of defect prevention techniques . Acquisition reform initiatives

allow contractors to adhere to one in-company quality standard, support the integration of commercial and military efforts, encourage variability reduction, reduce compliance with prescriptive "how to" requirements, and focus much more directly on meeting performance requirements. These changes will have a positive effect on both overhead and direct costs.

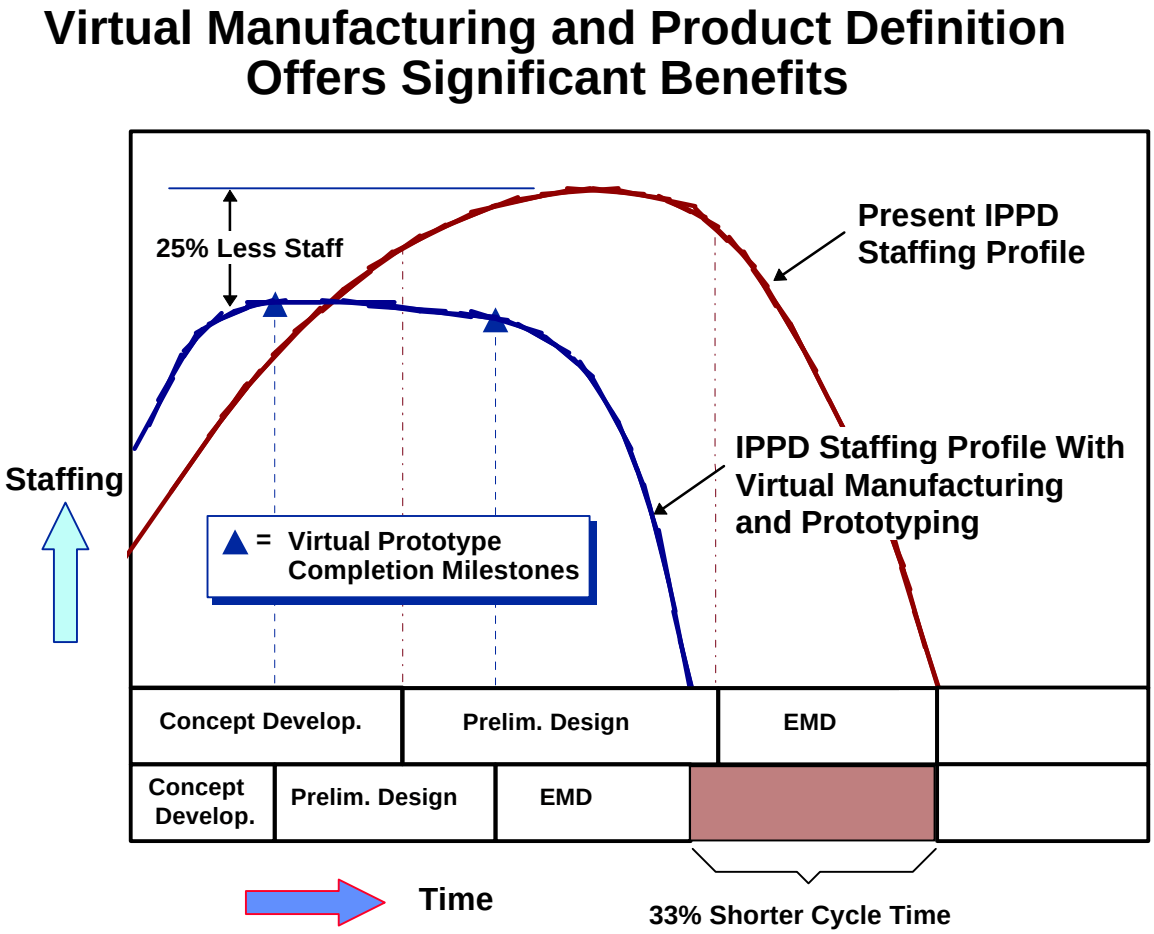


Figure 3-3. The Impact of Virtual Manufacturing in an IPPD Environment

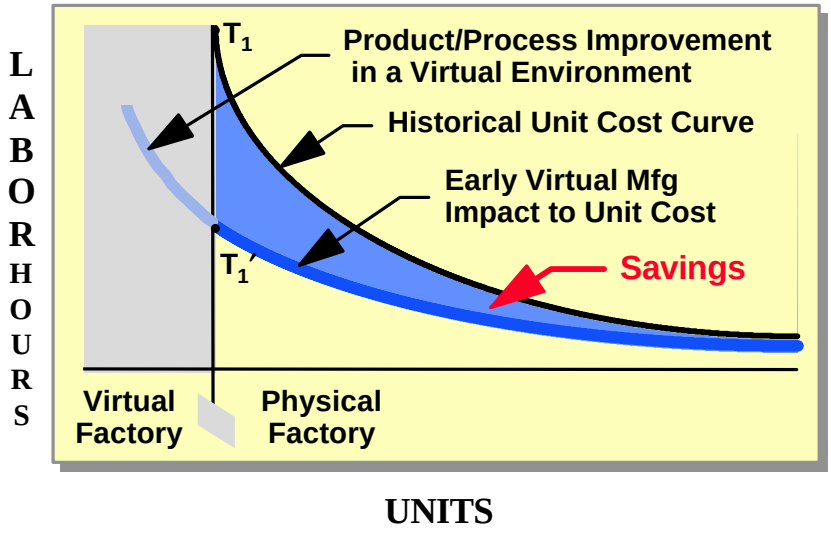


Figure 3-4 Product/Process Improvement in a Virtual Factory Environment

3.4 Contracting

This section discusses a variety of proposal and contracting issues associated with the implementation of MDG practices and concepts. It is intended to provide insight and guidance to manufacturing and quality personnel supporting these processes.

3.4.1 Contractual Implementation of Requirements

The major thrust of the acquisition reform initiatives (see Chapter 2, Acquisition Reform) has been to achieve the following changes:

1. Express RFPs and contracts in the form of performance based requirements, with the government no longer dictating engineering solutions or specifying how problems are to be solved.

2. Give contractors more control of the design, the configuration, and their own technical, management, and business processes.

3. Select high quality contractors to provide DoD products and services.

The major objective in this changed approach is to give contractors maximum flexibility in proposing and executing innovative and affordable approaches to fulfilling DoD program requirements.

The change to a performance based specification in the System Requirements Document (SRD) significantly alters the traditional contractual relationships. The contract establishes the *performance* that is required. The contractor's SOW delineates the *process* by which performance requirements will be met. The performance metrics and the procedures used to demonstrate the ability of the design to fulfill these requirements are based on the contractor's

plans. The new emphasis in the contracting process is on the analysis of the contractor's offer and on the contractor's past performance (via CPARS) rather than on the customer's contractual requirements.

In the reformed acquisition environment, the acquisition community should work with the using command to ensure that only a minimum number of performance parameters are contained in the RFP. The RFP, in other words, should contain only those performance parameters which are needed to characterize the major drivers of operational effectiveness and suitability, schedule, performance, and cost. (This approach eliminates the traditional problems associated with "required" and "desired" specifications.) MDG concepts should be reflected in these requirements either directly or indirectly.

For each performance or business parameter a desired (or objective) value is identified, along with a threshold value below which program performance is unacceptable. It is important not to over-specify the system, because this will limit the contractor's ability to optimize the proposed solution within these constraints. This approach gives the contractor the ability to characterize performance parameters and to look for the critical points in the performance curve so that "best value" decisions can be made in the design process. It is expected, but not required, that additional capabilities above the thresholds can be found within these constraints. The government will prioritize desired capabilities (or objectives) so that the contractor knows the relative importance of each. The bottom line is that the absolute requirements (or thresholds) must define a system that is "good enough," but every effort should be made to improve performance, cost, and/or schedule within program constraints.

This may present a dilemma for the contractors. Should they bid minimum cost to achieve threshold performance, or propose a solution which achieves objective performance at potentially high cost? This is a valid concern, since performance can be optimized for a given cost, or cost can be optimized for a given level of performance. If both parameter are allowed to vary, however, a unifying "measure of merit" is required to optimize the system. It may not be possible to identify such a metric because of the complexity of relating the performance parameters. Or it may not be desirable because it would restrict the contractor's options and creativity. The problem is further complicated by risk and technology. Objective performance may be achievable at lower cost through the application of new technology, but at a higher level of risk. This is a familiar dilemma which has been addressed by contractors in the past. In today's Performance Based Business Environment, cost, performance, and risk must be balanced to provide the best-value weapon system. The contractor tasks have not significantly changed. Contractors must understand the operational user's need, must understand performance tradeoffs (including affordability), and must present the most competitive proposal given the priorities and guidelines provided in the RFP.

Often a performance incentive or award fee or a combination of both is the best contractual means of emphasizing and managing optimization of program requirement within the bounds of objective and threshold values. Award fees are appropriate when the desired capability is not susceptible to finite measurement or depends upon a subjective evaluation. Performance incentives are appropriate when the desired capabilities (such as range, speed, or weight) are susceptible to objective measurement. An incentive should not be structured so that a contractor

is rewarded for superior technical performance when the cost of that achievement outweighs its value. Rather, an effective incentive provides clarity of focus, provides rewards which are sufficient to influence desired outcomes, and necessitates trade-off decisions between technical, schedule, and cost objectives.

One of the most critical aspects of establishing a performance based contract is establishing the process for verifying that the product or service meets the contract's requirements. Government requirements personnel, contracting personnel, and test and evaluation personnel must work closely together (and with the contractor) to define the acceptance procedures. The acceptance and performance verification procedures may be incremental, depending on the complexity and duration of the work. Properly structured acceptance and performance verification procedures tied to appropriate payment provisions will greatly enhance the enforceability of the contract for the government, as well as the value of the performance incentives for the contractor.

3.4.2 Contractual Protection of Proprietary Processes

As the practices sections on "Key Characteristics and Processes" later on in this document show, it is the intent of MDG to ensure that manufacturing processes are stable and capable. In many instances prime contractors and suppliers have developed, under their own funding, proprietary processes which give them a competitive advantage in the marketplace. While these proprietary processes may at times need to be demonstrated under MDG, this should be an exception rather than the norm. Often process validation and performance documentation can be demonstrated without delving into the proprietary core of the process. It is not the intent of MDG to obtain unlimited access to these processes or to obtain rights to these processes.

To ensure that proper protection is provided to contractors with proprietary processes, contractual clauses should be negotiated to allow for the proprietary process to be demonstrated without the threat of disclosure outside the government. It is left up to each Contracting Officer (CO) to negotiate with the contractor the proper form and wording of such clauses for each contract. The CO should make such determinations after coordinating with legal counsel and program management.

3.4.3 Contractual Coverage for Quantity-Based Recoupment

The proper understanding of maximum production rates is another important aspect of MDG. The most effective design of both a product and process can often be driven by the quantity to be manufactured. Historically, the government has been unable to successfully predict long range (or even short range) production quantities due to threat changes, budget constraints, and congressional adjustments to programs. Programs may even go "on-the-shelf" at the completion of development. Because of this, contractors need protection for having implemented MDG practices that generate contractor investments associated with quantity issues in cases where, for one reason or another, the program never progresses to the production phase, or where production quantities are significantly altered.

If a contractor capitalizes special tooling and special test equipment based on a predicted production rate that does not materialize, for instance, the program management team should

consider some type of compensation arrangement to allow the contractor to recoup all or some of his investment, depending on whether he has multiple customers for the product. One procedure to accomplish this is to include a quantity-based recoupment clause in the contract at time of award. It is important to note that this recoupment is a potential contingent liability for which funds must be committed within the program's current available funding. Caution must be taken to avoid potential Anti-Deficiency Act violations. It should be noted that command level or higher approval or coordination may be necessary.

3.4.4 Contractual Incentives for MDG Practices

MDG may create disincentives for some contractors in that its effect is to reduce overall acquisition cost and thereby reduce contractor profit on a cost contract. Some contractors may desire a contractual incentive or contractual funding to perform certain MDG practices (such as variability reduction activities). Others will perform these MDG recommended initiatives as a natural part of their work effort without additional funding. It is suggested that contractors be encouraged to view MDG practices as part of their general business strategies. Until these practices become a natural part of contractor cultures, however, carefully worded contractual incentives may be appropriate.

3.4.5 Draft Request for Proposal Considerations.

The Draft Request for Proposal (DRFP), and early industry involvement before the DRFP is written, should consider for discussion many of the features of MDG. Since the language and requirements in this handbook can be tailored, DRFP discussions will enable the SPO to gain insight from potential offerors on which requirements could cause problems, where cost savings may accrue, and what changes might allow for a more executable program. Following are some of the items that should be discussed with potential offerors.

Performance Objectives Discussions - Offerors should be afforded the opportunity to discuss requirements with user representatives. Specifically, the user should be prepared to address the importance of each requirement, the importance of each "desired" capability, and the potential for productive trades.

Cost Impacts of Changes in Performance Objectives - Offerors should be encouraged to provide the estimated cost impacts of changes in contract product performance objectives. The SPO could then optimize its performance objectives, pursue productive trades for “desired” capabilities, or use the money saved for enhanced capabilities elsewhere. Often a number of requirements can feasibly be relaxed, changed, or eliminated.

Non-Developmental or Commercial Products/Processes - Market research should be conducted to determine if commercial items are capable of meeting program needs. However, numerous government requirements can restrict the use of commercial items. The DRFP discussions should address whether prime contractors plan to use commercial vendors for components and which, if any, contractual requirements inhibit the effective use of commercial items.

Cost Impacts of Contract Requirements - Controlling costs is of major importance on all programs, especially on EMD programs where the contract type is often cost reimbursable. Therefore, DRFP discussions should also include a review of any program-peculiar requirements which increase direct costs and/or overhead. Often the government will unknowingly require contractors to accomplish work which is paid out of overhead accounts. Allowing prospective contractors to review the DRFP for impacts to overhead should lessen the chances of government requirements driving up these costs.

3.4.6 SOO Philosophy

In the new acquisition environment the user community establishes the performance requirements for a weapon system (including Cost as an Independent Variable) and then uses a process such as QFD (Quality Function Deployment) to address the cost-versus-performance trades, establish design objectives, and provide traceability through the specification process. In the acquisition documentation, the Statement of Objectives (SOO) defines the performance requirements for the weapon system. The contractor responds to the SOO with a Statement of Work (SOW), which defines the tasks and the performance capabilities which will result from those tasks. The contractor's SOW is incorporated into the contractual document to define the work to be performed and the resulting product performance.

The SOO philosophy is thus the end state of the redirection of acquisition reform from a prescriptive, specification based acquisition process to an objective, performance-based process. The end user defines the mission, mission environments, and desired results to initiate a program. These are translated into a Statement of Objectives (SOO) which is then presented to the prospective prime contractors. The prime contractor, subcontractors and the customer uses something like the QFD process to define and verify the functionality of the product and initiate the cost trades. In the new paradigm, cost trades give cost and performance equal weight in order to effectively address affordability issues, using a Cost as an Independent Variable (CAIV) approach.

3.4.7 SOO Guidelines

The program objectives for manufacturing as it affects the early acquisition phases are defined in the SOO guidelines for each major section. The specific objectives for each program will be based on the product's performance requirements, acquisition strategy, and acquisition phase. The early involvement of manufacturing engineering in the Concept Exploration and PDDR phases generates objectives which are directly tied to affordability and producibility. (See the Checklist of Contractor Tasks and Exit Criteria provided in an appendix to this document.)

3.4.8 SOW Guidelines

The *Manufacturing Development Guide* SOW guidelines (included in a subsequent section) provide the prime contractor with information on what is viewed as important for inclusion in the SOW, which is developed so as to demonstrate responsiveness to the SOO. The SOO thus provides a template for evaluating the contractor's SOW.

4. MANUFACTURING ENGINEERING'S ROLE IN IPPD

4.1 Introduction

In the collaborative design process which characterizes Integrated Product and Process Development (IPPD), the prime contractor, the major subcontractors, and the government customer work together in an Integrated Product Team (or IPT) environment. The objective of the IPTs is to transform user-defined needs into a performance based system or component specification, and then to provide a plan for effectively executing and validating a design that fulfills the performance requirements. An essential condition of the IPPD environment is that the contractor's manufacturing engineering function be directly involved early in the product definition process. Another essential condition is that the Systems Manufacturing Engineer (SME) actively lead the government's participation in the IPPD process throughout all phases of a program. This chapter describes the IPPD process and the roles of the contractor's manufacturing engineering (ME or CME) function as well as the government's Systems Manufacturing Engineer.

At the earliest phase of a new weapon system acquisition, the development of the user's requirements initiates an interactive process (involving both the government customer and prospective contractors) in which the requirements are defined, evaluated, and prioritized with respect to budgetary and schedule constraints. Processes such as Quality Function Deployment (QFD) are often used in this environment to focus all parties on the most essential elements of the requirements and to define the interdependence between requirements.

Pre-proposal efforts and exchanges (in such forms as dialogues with industry, study contracts, reviews of draft documents, and technology maturation contracts for risk mitigation) serve to inform the prime contractors of the customer's need. Contractor feedback to the government during this period assists in identifying the cost and risk drivers in the proposed acquisition.

The sequence just described is different in a number of respects from the more traditional approaches used in earlier acquisition programs. In the IPPD environment the participants interact freely throughout the design and development process, exchanging information, and analyzing cost/schedule/performance trades together in accordance with an open communications philosophy. This kind of close participation between the customer and the contractor fundamentally changes their relationship. It tends to eliminate the potentially adversarial relationship which has at times existed in traditional acquisition approaches. It also creates a new level of trust, since the innermost proprietary and business interests of the prime contractor and the customer are visible to the entire IPT.

Joint contractor/government (that is, supplier/customer) IPTs are encouraged as a progressive feature of acquisition reform. It is incumbent upon all parties in this cooperative arrangement to assure that sensitive contractual information is protected. The sharing and the open communications should benefit all participants by minimizing unnecessary efforts and costs and by maximizing user satisfaction.

Within the IPT structure the design trades needed to balance the product design with the manufacturing process will require accurate information about the capabilities of the factory floor. The data and the analytical tools used to define the process capabilities must be made available to all of the IPT functional members by the ME. As the design evolves, fabrication and assembly options become fixed by the details of the design, the materials selection, and the tolerances and other physical aspects of the proposed part. The ME must be able to translate the consequences of the design decisions into producibility and affordability metrics to help the IPT make informed and balanced trades between design options. The ME's role is to assure that producibility is optimized through the robustness of the product design as well as the processes. There will be occasions when this or earlier phases will be revisited from the production phase. A major modification or integration of additional capability into a production program may result in SPO activities that are essentially new developments from the IPPD perspective. The roles of the ME and SME change from phase to phase. In the earliest activities the emphasis is on matching product requirements with the materials and process capabilities which affect cost and schedule risk. As the program moves into EMD, the level of involvement increases as the details of the design evolve. Some of the changes between Pre-EMD and EMD by section are as follows:

- Design trade studies address producibility and affordability.
- Cost models are continuously updated.
- Materials selections lead to process requirements.
- Process requirements are matched with the process capabilities.
- Key characteristics are assigned.
- Risk mitigation activities are launched for process capability deficiencies.
- Manufacturing simulations are used to verify product and tooling fit.

There will be two distinct types of ME activities during the production phase. The first will focus on improving the efficiency of the existing or derivative manufacturing processes (variability reduction).The second will be IPT participation in the integration of major systems improvements or engineering changes. Variability reduction will be addressed as a unique ME activity in the rest of this section. Improvements and engineering changes should be treated by the ME as if they were new starts, that is, by referring back to the appropriate place (Pre-EMD or EMD) in the MDG.

4.2 Rationale

The objective of the EMD phase is engineering *and* manufacturing development, not engineering *then* manufacturing development. The IPT must be as concerned with the manufacturability of the proposed design as with its functionality. Just as component testing confirms the proposed parts *functionally*, the ME must have the same quality of data about the manufacturing process to fairly represent the *manufacturability* of the parts. Process capabilities

from the existing factory floor or data collected from benchmark industries can be used by the ME to help establish the bases for affordability analysis. Unique materials or tolerances for which manufacturing data does not exist may require process testing, demonstration, or simulation by the ME. These efforts would be functionally equivalent to the testing that is currently done by the design engineer to reduce risks on new component designs.

The transition to production at the end of EMD has traditionally brought with it many unpleasant surprises in the form of producibility changes needed to resolve low process yields, poor quality, or failures in assembly and final check out. Low Rate Initial Production (LRIP) was introduced as one mechanism to mitigate the transition to production risks. LRIP does not address the root cause of the transition to production problems, however. It merely adds time and money at the end of the formal EMD phase and allows the problems that surface to be resolved without jeopardizing the program. ME activities must encourage an earlier focus by the IPT on the root causes of affordability, producibility and manufacturability problems. Focusing on these problems during development helps to avoid the transition to production problems later on.

In part because it directly involves the manufacturing engineering function early in the product definition process, the IPPD team concept paves the way for early identification and mitigation of producibility, cost, and other risk areas, such as potential transition-to-EMD or production risks. (In the previous acquisition environment these were classic contributors to cost and schedule overruns.) The manufacturing engineer should lead producibility studies and analyses conducted by any IPT that influence product or process design. The contractor's formal IPPD procedures and processes should detail the roles and responsibilities of the manufacturing engineering function on the IPT (along with those of other team members), and should ensure that all the resources, skills areas, data and tools needed for the IPPD are identified, are available to the team, and are effectively utilized.

During CE and PDDR, the manufacturing engineering, production operations, quality, tooling design and fabrication, industrial engineering, and supplier members of the IPTs ensure a continuous focus on critical producibility, manufacturability, and affordability issues associated with the design. The selection of materials based on performance requirements, for instance, leads directly to the identification and evaluation of processes which may require further development. The EMD role becomes one of preparing the initial planning to support the build of the pre-LRIP test units and the LRIP planning. As materials are selected, the mapping to manufacturing processes becomes clearer. With the processes and requirements identified, the application of process capability data from the contractor's and key supplier's Manufacturing Capabilities databases identifies the areas where action is required to improve capabilities or change the design or design requirements to reduce cost and schedule risk. Variability reduction in the production phase requires the ME to uses selection and prioritization tools, such as the Pareto approach, to find and focus on the processes that will provide the best return on investment if improved.

Other approaches to prioritizing improvements include simulation of the factory and cause and effect analysis of factory quality data. Regardless of how candidate processes are selected, the objective for the ME is continuous improvement of the efficiency and effectiveness of factory operations. Candidate processes should also include the support operations or "above the factory floor" activities. Data is the basis of all decisions.

As the program moves into Production, the ME and the SME become leaders in the continuous improvement of the product and processes. In this phase the IPT has two areas of focus. First, using the field and factory data, the manufacturing processes are made more robust. Second, as new performance requirements are identified, the design improvements are planned and introduced in a disciplined manner using all of the MDG tools as appropriate in block changes. With the Statement of Objectives (or SOO) defining the expectations of the customer, the contractor's formal documentation of the IPPD process (and the roles and responsibilities of the participants) assures that no design decision takes place in a vacuum.

Contractors who are experienced in the successful application of IPPD processes have developed "best practices" which clearly define policies and process flows for the IPTs. Beginning with the initial development of performance-based requirements by the customer. And by the IPT in the CE phase, QFD methods or similar processes are employed to focus on the best design responses. The contractor typically hosts the QFD-type activities in the CE phase as a vehicle for further clarifying the design performance objectives. This has proven to be an excellent means of addressing any remaining cost and performance trades, and of increasing customer/user confidence in the team's approach.

4.3 Guidance

The contractor should demonstrate an understanding of and experience with IPPD environments, including how the proposed program management structure embraces IPPD concepts. IPT participants should be specially trained in the principles of IPPD as well as the design tools which will be utilized on the program. The contractor should document how IPPD processes will be employed on the program to assure that all participants understand their roles and responsibilities and perform accordingly. In particular, the contractor's procedures and processes should define the expected outputs from the team, with special emphasis on trades made by the team. Design trades made at this point should begin to reflect the performance capabilities of the manufacturing processes available for the fabrication and assembly of the proposed design. The SME focus is on the matching of process capabilities with process requirements, since this is the major source of cost and schedule risk in a program. The SME and his or her contractor and supplier counterparts on the IPT work in concert to assure that risks are identified early in the program and that progress is monitored throughout the program.

The contract should provide for a QFD-type review of the performance requirements and the operating environment of the weapon system. With the emphasis on affordability, the cost-versus-performance trades made prior to the release of the System Requirements Document should be carefully reviewed with the contractor.

The contractor's Manufacturing Engineer and the SME participate in the IPT to the extent required by program and tasks. In a large weapon system procurement the contractor may assign several MEs, including representation of several subdisciplines such as Tooling, Test Equipment, Industrial Engineering, and Process Engineering, as well as product quality assurance. The government presence may include full time assignments for an SME and a Quality Engineer who participate in the IPT and provide government insight. The list which follows identifies the Pre-

EMD tasks which are performed by the contractor ME on the IPT. The SME's responsibilities include insight to these tasks.

- Participate in design trade studies.
- Develop preliminary Product Cost Model.
- Initiate mapping of the Key Characteristics Process for requirements.
- Establish data collection for process capability requirements.
- Initiate process development as required.
- Verify production flow through simulation.
- Involve Key Suppliers in MDG best practices.

In the EMD Phase the activity levels of the ME and SME increase with the detailing of the concept design. Key characteristics are identified which must be mapped to key process characteristics, which are then evaluated against the contractor's manufacturing capability database. Areas where the materials chosen or the process capabilities do not support the design result in a design change, a process development, or other action to mitigate the risk. The initial manufacturing planning for LRIP occurs during EMD. Many contractors are using assembly simulation tools to evaluate part-to-part and part-to-tool fit during this phase. The level of detail of the production cost model is increased and actions are usually required to offset cost growth during EMD.

SME participation focuses on those aspects of the contractor program that address risk in the contract as well as the Production Phase. Key areas of interest include the robustness of the design and processes for meeting the requirements; understanding of the process capability issues and monitoring of the required process improvements; evaluation of the LRIP planning; and validating of the production cost model. A list of EMD phase tasks for the ME and the SME includes the following:

- Refine and monitor production cost model.
- Participate in design trade studies.
- Implement single process initiative and commercial specifications.
- Map processes to key characteristics.
- Implement manufacturing capability assessment plan.
- Integrate key supplier activities into manufacturing activity.
- Develop LRIP production plan.

- Validate production plan through simulation.
- Implement variability reduction.
- Implement defect prevention activities.

The ME will be the focal point for helping deploy the philosophy and the enabling technologies from the SPO and the contractor facilities to both the design center and the factory floor. At all times the ME is a participant, and occasionally is a teacher or mentor to promote VR. Continuous improvement of the factory processes requires a disciplined approach to the analysis of process control data and field data. Identifying the causes of variation and creating affordable improvements is critical to achieving production cost goals.. Product improvements based on new requirements, and opportunities to make value-added improvements by changing design requirements and increasing robustness are common occurrences in the Production phase. They require the application of the MDG best practices used in Pre-EMD and EMD. The SME is often a major participant from the SPO during this phase of a program, providing liaison on technical issues and reviewing contractor process and yield data for insight into process improvement efforts. A list of Production phase tasks for the ME and the SME includes the following:

- Monitor process variation and initiate improvements.
- Plan for cost effective implementation of changes.
- Implement Lean initiatives for cost management.
- Maintain production cost model.
- Continue defect prevention program.

4.4 Lessons Learned

The use of IPTs working within the IPPD process has demonstrated clear benefits in reducing product design time as well as cost. With representatives of all stakeholder functions involved from the beginning, the team integrates the design, manufacturing, quality, and other key personnel into a focused, results-driven unit. The inclusion of customer and supplier personnel has further increased the effectiveness of IPTs in achieving high quality product definition. Most of the DoD's more recent product design efforts have employed IPTs and reported both cost and schedule benefits. Reduced engineering changes result in shorter design development times and reduced labor, since rework of the design is diminished. Reductions in tooling design and fabrication costs as well as rework in LRIP and early production are additional benefits of the IPPD process.

Customer participation creates an atmosphere which supports cost effective performance based resolutions to design trades. Supplier participation provides a vehicle for a best value approach to the trading of performance and cost objectives at the lower levels of the design effort.

For these reasons, the disciplined IPPD approach has become a preferred approach for most defense contractors.

Design IPTs may be replaced by factory cells or focus teams that are formed to address a production problem or station. Mastery of all the VR tools and techniques is not necessary, but the ME must have a good working knowledge of the full tool set of variability reduction techniques. Misuse of variability reduction tools can create misinformation and could adversely impact the processes. The maintenance of a Manufacturing Capability database derived from statistical process control and other factory data collection systems provides a source for continuous process improvement. The ME leads the problem solving process, addressing both the processes and the design to achieve a balanced and affordable product. Scrap and rework levels have been significantly reduced by contractors applying these practices, and improved schedule performance and cost reductions also result.

The ME's participation in planned product improvements provides the benefits described in Chapters 7 and 8 as parts of those phases are revisited. Additionally, product changes must be introduced into the existing factory in the least disruptive and most cost effective manner. Changes to tooling and test equipment, processes, and the product flow require coordination and planning. Successful companies have used the ME to model before and after processes, employing simulation techniques to reduce errors which would impact cost and schedule.

4.5 Recommended RFP/Proposal Content

4.5.1 Government Statement of Objectives (SOO)

See Chapter 7, Section 7.1.1 "Suggested Pre-EMD SOO Content," Chapter 8, Section 8.11 "Suggested EMD SOO Content," and Chapter 9, Section 9.11 "Suggested SOO Content."

4.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to address the topics below in their submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Formal processes and best practices to be followed by the contractor's integrated product teams.
- Means used to involve the government customer, the required internal disciplines (including manufacturing engineering), and key subcontractors in a collaborative design process.
- Prior experience with IPTs.
- Identification of functional representation on the IPT at the organization chart level.
- Roles and responsibilities, reporting requirements, and program metrics to be followed by the IPTs.

4.5.3 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program)

- Manufacturing participation in product development is evident through the fulfillment of MDG-related exit criteria, such as leadership in producibility studies, evidence of objective process knowledge, and analysis of process cost implications in affordability risk studies.
- Product Cost Model demonstrates that the cost objective is achievable.
- Manufacturing process design considered in product design engineering practices.
- IPPD processes employed to define initial production concepts.
- Customer/user and supplier participation documented in IPT and requirements definition activities.
- Appropriate consideration of multi-functional IPT inputs reflected in documentation of trade-off decisions.

Milestone II (Approval to Enter EMD)

- Manufacturing participation in design is evident through the fulfillment of MDG-related exit criteria, such as leadership in producibility studies.
- Evidence that process considerations have influenced the product design.
- PCM demonstrates that cost objective is achievable, and associated risk reduction tasks are identified in the IMP.
- Results of producibility studies are accounted for in the product design approach.
- Customer/user and supplier members actively participated in IPT.
- Process maturation plans have been employed.

Interim Event (corresponding to historical Preliminary Design Review):

- Manufacturability of the design is evident through fulfillment of the MDG-related exit criteria, such as process maturity plans.
- Validation of process capability index is being confirmed for key processes using representative materials
- Design of experiments has been used to define a first approximation to optimum setting for process attributes.

Interim Event (corresponding to historical Critical Design Review):

- Manufacturing Engineer and supplier participation in IPTs and design trades.
- PCM demonstrates that cost objective is met.
- Key characteristics and key processes are matched for prime and sub contractors.
- Process capabilities are adequate for product requirements for prime and subcontractors.
- Simulations have validated the assembly process.
- Supplier participation in IPTs assures a robust process design.

Interim Event (corresponding to historical System Verification Review):

- Manufacturing Engineer leads LRIP IPT activity.
- PCM demonstrates low risk in achieving cost objective.
- Simulations verify and validate assembly processes prior to LRIP.
- Risk reduction tasks for processes are completed successfully.

Integrated Master Plan (IMP) Content

The topics which the offeror's IMP for Production should include the following areas:

- Scheduled IPT meetings.
- Scheduled periodic review of process and field data.
- Block change schedules for incorporation of process improvements.

4.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

4.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- The IPPD processes which the offeror proposes to employ.
- The proposed approach to populating multi-functional teams and ensuring participation by suppliers and/or customers.

- A description of previous experience with IPPD processes (including performance metrics and demonstrated cost and schedule benefits).

- Plans to introduce and institutionalize the IPPD process in the offeror's organization (if the offeror has no previous IPPD experience).

- A description of the methodology used by the IPT for validating process cost and capability data to support IPPT trade decisions.

4.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- An established or proposed IPPD process, including team member roles and responsibilities.

- Previous experience which demonstrates cost and schedule benefits realized by IPPD processes.

- Presentation of a viable plan which can reasonably be expected to effectively institutionalize IPPD in the offeror's organization (if the offeror has no previous IPPD experience).

- Data on existing process cost and capabilities and evidence that the data has been used in design trade studies.

- An established, or proposed, demonstration or analytical approach to validate that the process capabilities needed to achieve the stated affordability requirements are within industry standards or identified as cost and schedule risk issues.

5. ENGINEERING FOR AFFORDABILITY

5.1 Introduction

Product affordability, taking into account the entire life cycle of products, has become an essential requirement for weapon systems acquisition programs. For both new programs and existing system upgrades, affordability must be considered along with quality, reliability, and technical performance in all program phases. Product cost must now be a consideration from the earliest concept exploration activities through the design, development, production, and sustainment phases of a program. One of the primary purposes of the MDG is to improve product affordability, a goal that can be achieved through the use of a variety of tools. One such tool that has strong ties to engineering for affordability is Production Cost Modeling (PCM), which is discussed as a practice in subsequent chapters related to the specific program phases. This chapter provides a general discussion of engineering for affordability and cost requirements that apply to all program phases. It also introduces other tools in addition to PCM that can be used in a variety of circumstances.

Two methods of defining production cost that have come into widespread use in the defense industry are Average Unit Production Price (AUPP) and Design To Unit Production Cost (DTUPC). DTUPC is normally defined as the production cost term (as defined in Figure 5-1) divided by the total production quantity (DTUPC = Production Cost/Production Quantity). There is no precise, universally accepted definition for AUPP, but perhaps the most commonly encountered definition is the flyaway cost (as defined in Figure 5-1) divided by the production quantity (AUPP = Flyaway Cost/Production Quantity). An alternate definition that has been applied on several defense programs is to require the inclusion of support equipment costs in with the flyaway cost (AUPP = [Flyaway Cost + support equipment cost]/Production Quantity). Regardless of which term or definition is selected as the instrument for establishing the production cost requirement, it is absolutely essential that all parties understand the definition and all the factors that influence it.

Even though program cost requirements will usually be related to production costs, the Life Cycle Cost (LCC) is the ultimate measure of true product affordability (see Figure 5-1). Because of this, logistics and support issues and LCC models should be addressed early in the program. Environmental issues associated with manufacturing, operation, sustainment, long-term storage, and disposal of the product should also be addressed early on. For example, when a producibility study addresses material selection, the analysis needs to focus on non-selection of hazardous materials, acceptable substitutions for which can generate significant life cycle cost avoidance.

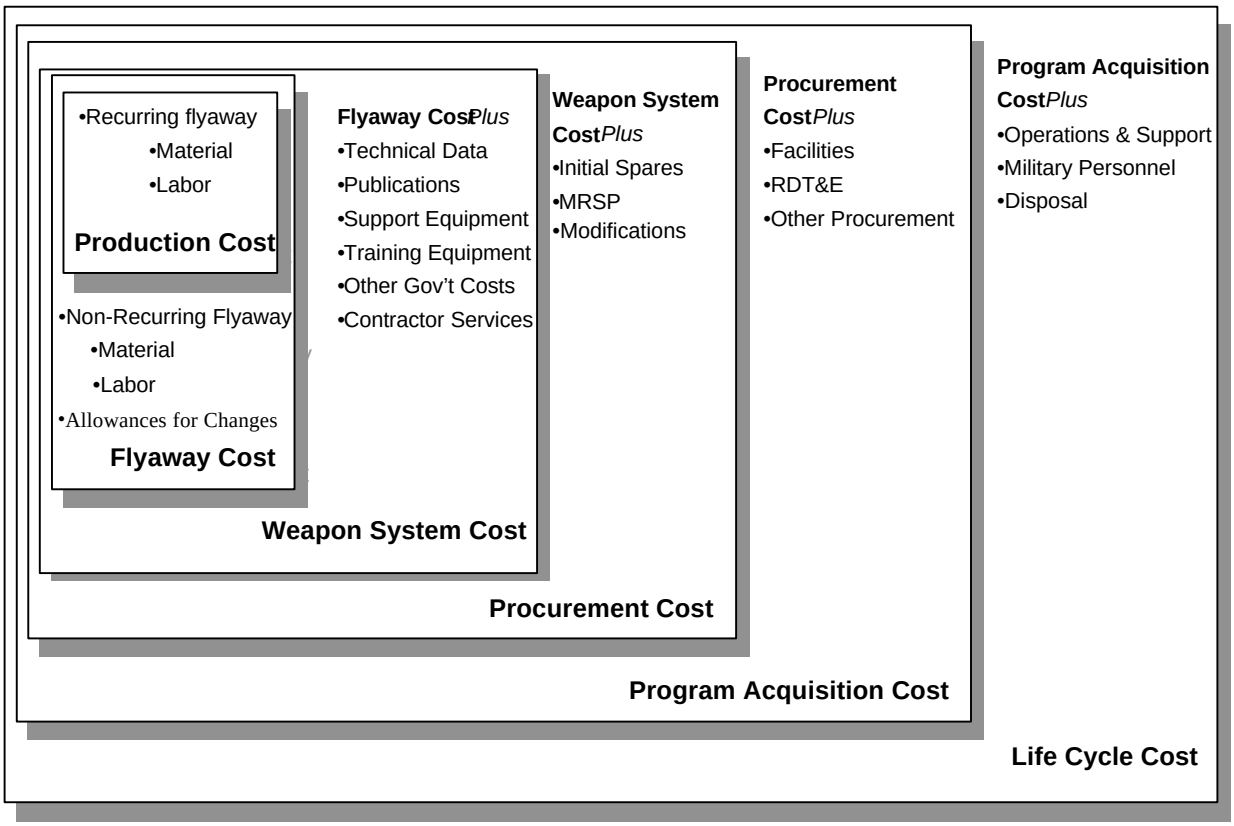


Figure 5-1. Life Cycle Costs

5.2 Rationale

The need for significantly more affordable Department of Defense (DoD) programs in a limited budget environment has led to major changes in the way development programs are managed and executed. Life Cycle Costs are a crucial factor in determining weapon system feasibility, and all new programs must consider cost as a primary requirement. Cost impacts must be a consideration in the requirements allocation and flowdown process as well as in all requirements, development, and design trade studies.

Several factors have been behind the increase in weapon system costs, many of which have their roots in increasingly rapid technological advancements. In recent years, parts obsolescence has become a bigger and bigger problem, driving costs for redesign, production and maintenance. Sometimes related to parts obsolescence, diminishing manufacturing sources have also been a dilemma. Developing new sources of parts and subsystems is always a costly prospect, especially for obsolete technology for which markets are limited. With technological advancement, design complexity has also greatly increased, often resulting in extended development times. Besides the increased costs associated with longer development periods, this serves to increase the risks of obsolescence and diminishing sources. Parts control also becomes more critical and costly with increases in system complexity.

Environmental impacts associated with manufacturing, base level operations, depot sustainment activities, storage, and disposal of the product must also be a consideration in the development effort in order to avoid “hidden costs” that can drive up the latter stages of the life cycle cost.

5.3 Guidance

Engineering for affordability is simply the practice of developing and designing systems that offer the best value solution over the entire product life cycle. It requires the early consideration (during the product definition and development process) of manufacturing, test, support, and disposal costs. It must provide the tools and flexibility to trade product performance against projected production costs. A basic tenet of this philosophy is that all Integrated Product Teams (IPTs) and engineering organizations be accountable for considering the impact of engineering decisions on program affordability. Affordability metrics, such as producibility analyses supporting the economic wisdom of the design alternatives selected, should be developed, retained and analyzed as part of continuous improvement activities. This practice is exemplified by Wright Laboratories at Wright Patterson Air Force Base, where the engineers responsible for orchestrating “Advanced Technology Transition Demonstrations” are also responsible for documenting the estimated costs associated with implementing such advanced technologies into the manufacturing environment. These cost estimates benefit product and process design engineers throughout the defense industrial base when they, in turn, are called upon to evaluate design alternatives within the context of affordability impact.

The need to evaluate cost projections early in the product development process will necessitate the development and validation of dependable cost models and an integrated design/manufacturing simulation/cost estimating capability as shown in Figure 5-2.

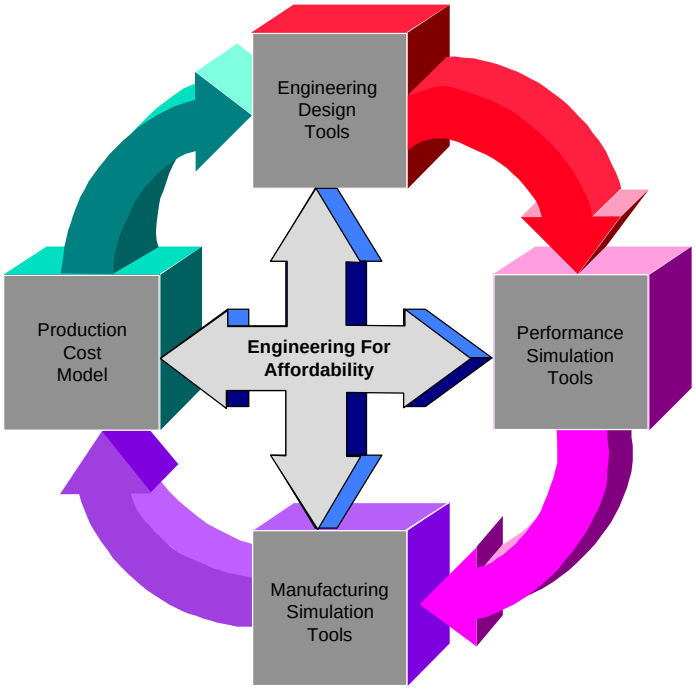


Figure 5-2. Integrated Engineering for Affordability Tool Set

Cost partitioning is the practice of distributing the AUPP or production cost requirement in accordance with the requirements allocation or system concept. The distribution is then refined periodically to the subsystem and component level as the concept matures. It thus supports a formal risk mitigation process. Cost partitioning should be used to track IPT ownership of specific cost allocations and may provide a framework for the final Production Cost Model.

Design-to-cost is a methodology in which the cost allocations established through cost partitioning are interpreted as design requirements and pursued rigorously throughout system development and production. Rigorous implementation of DTC makes cost a design requirement during the development and design trade study activities, with traceability back to system affordability. It also establishes design cost responsibility at the IPT and individual team member level. Other concepts that should be considered during development activities because of their potential impact on life cycle costs are "Design for *x*" (DF*x*) methodologies, "Hidden environmental costs," design robustness, and designing in flexibility/adaptability.

"Design for *x*" is a set of affordability tools that has become widely accepted in both the commercial and defense industries in recent years for facilitating cost reduction activities. The specific application tool sets available include Design for Manufacturing, Design for Assembly, and Design for Service.

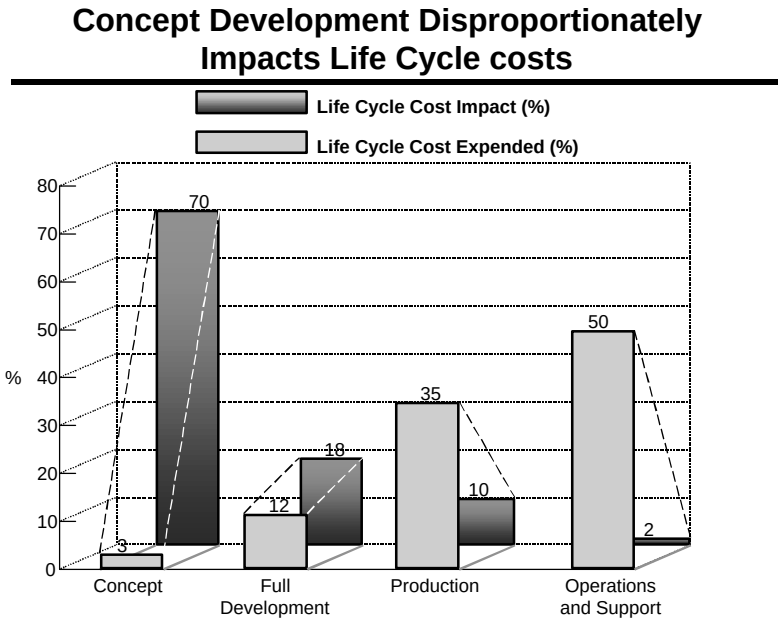
"Hidden environmental costs" that can adversely impact system affordability can include the added costs for special handling, storage, and inventory accounting and control of hazardous materials, such as those on the EPA list of the most toxic chemicals. Such increased costs accrue not only at production sites but also at operational bases and military depots, largely attributable to peculiar long-term storage environmental requirements, and disposal costs if unusual or

potentially hazardous materials are called for in the design. Accordingly, a comprehensive environmental impact assessment should begin during initial development phases and be updated throughout design and production. The objective is to promote early product design modification and risk reduction activities to avoid hidden environmental costs later.

Design robustness becomes an issue when designs are less robust against variability in manufacturing processes (that is, when they are more affected by process variability) than is desirable. When this is the case, several cost drivers may be present. Incapable or marginally capable processes increase the risks of the generation of defective products, resulting in increased failure costs. More stringent and costly controls over processes may be necessary to reduce defects. Processes may need to be redesigned or more expensive equipment procured. Or product verification activities may have to be increased. The robustness of a design is inversely related to the number of key characteristics inherent in the design (see subsequent sections of this document on key characteristics). Designing products with fewer key characteristics, or redesigning products to eliminate key characteristics is therefore one method of cost avoidance.

Designing in flexibility/adaptability would have its greatest benefit on programs which have several variants planned for production and deployment. Such designs maximize the use of common processes and production lines and minimize the number of special or redundant processes that need to be implemented. Other cost avoidance benefits of these designs include the fact that fewer maintenance/support processes are required once the systems are deployed.
Lessons Learned

Studies have repeatedly shown that the best opportunities for system cost reduction occur during early program development phases (Figure 5-3). The use of production cost modeling, cost partitioning, design-to-cost, design robustness approaches and other affordability engineering tools and concepts in an IPT environment promote awareness at all program levels of the cost impact of design decisions made during the Concept Exploration (CE) and PDRR phases.



Source: **Producibility Measurements Guidelines**, NAVSO P-3679, Dept. of the Navy, August, 1993

Figure 5-3. Impact of Early Activities on Life Cycle Cost

Application of the Design For *x* methodologies has been proven to be an especially effective means of assessing the manufacturing/assembly/test and service costs associated with various design options. Use of DF*x* also provides an effective means of targeting complex or high-risk designs for modification during cost and risk reduction activities. Figure 5-4 presents a summary of the benefits obtained from the application of Design for Manufacturing and Design for Assembly processes in 66 published case studies. (Source: "A Decade of DFMA Research," G. Boothroyd, Proceedings of the 1994 International Forum of Design for Manufacture and Assembly, June 13-14, 1994.)

Category	# of Case Studies	Average Reduction (%)
Part Count	55	57
Separate Fasteners	12	72
Assembly Time	37	63
Assembly Cost	16	45
Product Cost	15	51
Product Development / Time to Market	4	50
Manufacturing Cycle Time	6	58

Figure 5-4. Design for Manufacturing and Assembly Results.

Previous experience with DTC has been disappointing, in that a cost "goal" traceable to the Statement of Work (SOW) was established, and the entire effort became little more than a matter of at tracking and comparing the production cost estimate to the "goal." In many cases, the ground rules and assumptions (rate, volume, schedule) were not updated to reflect program changes and as a consequence the production cost estimates had no validity. To be effective and credible, two philosophical changes in implementation must occur: (1) DTC values must be tied to the established threshold of affordability or, if available, the production cost requirement; and (2) the Production Cost Model must be validated, maintained, and kept up to date with all program ground rules and assumptions.

Finally, experience has shown that the most effective use of any affordability engineering practice is achieved when the available tools and practices are flowed down to suppliers who provide key or complex subassemblies or components. With the increased emphasis on the use of suppliers by prime contractors in the defense industry, providing resources and training for supplier application of DTC and DF*x* type practices creates an environment in which all program stakeholders can benefit from reduced product cost and improved product quality.

5.4 Recommended RFP/Proposal Content

5.4.1 System Specification Requirement

Production Cost The [program name] average unit production price (AUPP) shall not exceed $_____ in [constant FY __ dollars] for [total volume or target volume and range] production units at a maximum production rate of [average rate/specific planned rate/target rate and range] per month. (Identify and define cost elements included and/or explicitly excluded). Cost allocations for Complex Items (CIs) shall be identified in the CI Development Specifications. [The average unit production cost goal for the system is $_____ in [constant FY __ dollars] for the same volume and rate(s)]

5.4.2 System Specification Verification

Production Cost. The [program name] AUPP requirement shall be verified by analysis using a Government validated PCM with the addition of the indirect costs not contained in the cost model; profit; and a recognition of the current status of the cost risk of the estimate produced by the PCM.

5.4.3 Government Statement of Objectives (SOO)

In Chapters 7, 8, and 9, see Sections 7.1.1, 8.1.1, and 9.1.1 for Suggested Statement of Objectives (SOO) Content as applicable for the program phase.

5.4.4 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Incorporation of cost in design/performance trade studies.

- Incorporation of cost in requirements flowdown.
- Implementation of cost requirements at the IPT level.
- Flow down of cost targets to key suppliers.
- Offeror's formal cost risk management measures.
- Availability of "Engineering for Affordability" tools and training to suppliers.
- The planned implementation of formal cost avoidance initiatives, programs, tools, and techniques.

5.4.5 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program):

- Preliminary production concepts identified. Preliminary cost partitioning of major assemblies accomplished.

Milestone II (Approval to Enter EMD):

- Cost vs. performance trade studies defined.
- Results of cost vs. performance trade studies obtained.
- Cost requirement flowdown refined.
- Preliminary environmental impact assessments completed on production and operations by-products, sustainment impact, long-term storage, and disposal of end items and related hazardous materials used in manufacturing and sustainment processes.
- Cost management/reduction systems developed an implemented.

5.4.6 Contract Data Requirements List (CDRL) Guidance

- No formal CDRLs are suggested for this section.
- (DUE) Environmental Impact Assessment at Milestone II.

5.4.7 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for cost requirements allocation and flowdown.

- Documentation practices for cost requirements allocation and flowdown.
- Description of formal programs/tools/techniques to be used in engineering for affordability to maximize cost avoidance in manufacturing and sustainment.
- Methods for including cost considerations in design trade studies.
- Description of requirement cost partitioning processes.
- Description of cost risk identification/mitigation processes.
- Description of contractor's past performance in cost requirements management under the IPT concept.
- Flowdown of engineering for affordability tools, techniques, and practices, along with related training, to appropriate suppliers.

5.4.8 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Engineering for Affordability practices should be based upon:

- Established practices for cost requirement allocation and flowdown.
- Planned implementation of resources and tools for the consideration of cost requirements in the design trade studies.
- Planned use of formal cost avoidance initiatives/programs such as those described above.
- Planned use of cost risk identification/mitigation processes.
- Past performance of prime contractor and key suppliers in establishing and meeting cost allocations.
- Plans for flowing down to appropriate suppliers cost avoidance initiatives/programs such as those described above.

6. QUALITY SYSTEMS

6.1 Introduction

Within the context of a foundational quality management system such as ANSI/ASQC Q9001 (ISO 9001), it is often beneficial to implement tools and techniques which go beyond traditional quality management techniques in order to ensure the final product meets user needs. Such tools and techniques focus on the development of producible, maintainable products and on stable and capable manufacturing processes. They are especially useful for assuring the quality of highly technical, state-of-the-art products and processes. Integrating the use of these state-of-the-art tools and techniques with their foundational quality systems, some companies refer to their quality systems as advanced systems, or, in documented procedures, refer to Advanced Quality Techniques. Elsewhere, in order to emphasize that accountability for the quality of work should be placed on those performing the work, these tools and techniques are considered part of a systems engineering process or Integrated Product and Process Development (IPPD) system. Regardless of the terms used, it is engineering and/or manufacturing personnel who usually should be implementing tools and techniques whose primary purpose is to prevent the generation of defects in the products being produced.

This chapter discusses quality systems and their evolution in order to bridge the gap between traditional defect detection quality control methodologies and current state-of-the-art methods used to assure quality. Since many of the specific practices addressed elsewhere in this guide are grounded in modern quality system tools and concepts, including key characteristics, variability reduction, supplier management, virtual manufacturing, and product and process validation, this chapter doesn't repeat what is found elsewhere, but addresses an overall systems approach for assuring quality. Elsewhere in this guide, the tools and techniques that make up state-of-the-art quality systems are referred to as *defect prevention techniques*. This is consistent with similar guidance documents that have been developed through other acquisition reform efforts, such as the Joint Aeronautical Commanders Group (JACG) document titled *Engineering and Manufacturing Practices for Defect Prevention: A Guide for Aerospace Acquisition Management Teams.* This is the prime source for state-of-the-art quality systems requirements. Section 4 of the JACG policy guidelines, which discusses attributes, tools, and business practices associated with successful modern Quality Systems, is provided in Appendix II to this document. Further information on defect prevention tools and processes not discussed in the MDG itself can be found there. These principles are applicable to all phases of an acquisition program.

6.2 Rationale

Where conventional quality systems have emphasized the detection of defects after the fact, state-of-the-art quality systems are designed to prevent the production of defective products in the first place. In the IPPD acquisition environment, Quality Engineers, like Manufacturing Engineers, are key members of the program IPT. They participate directly in every part of the program, from the CE and PDRR phase of the design process all the way through to production

and support. Their role is to ensure an integrated, multi-functional approach to quality throughout the product life cycle.

As developed by world-class companies around the globe, modern State-of-the-art Quality Systems are implemented outside the traditional quality assurance organizational structure. With the widespread embracing of TQM philosophies, personnel in value-added function areas (rather than dedicated quality personnel) are tasked with responsibility for the quality of their own work and empowered to make key decisions affecting that work. (*Value-added,* as used here, refers to work performed by direct labor functions which adds tangible value directly to the product being produced.) In response to these developments, some companies have begun questioning whether there is still a need for an independent, dedicated quality functional organization.

However, far from eliminating the need for quality professionals, the acceptance of responsibility for their own work by other members of an organization frees up the modern quality organization to perform work consistent with the long-term focus of state-of-the-art quality systems.

6.3 Guidance

Quality systems should satisfy three top level objectives. (1) They should achieve and sustain the quality of the product and continually meet the customer's needs; (2) They should provide confidence to management that the appropriate level of quality is being achieved and sustained; (3) They should provide confidence to the customer that the appropriate level of quality is or will be achieved in the product provided. No one prescribed system is preferable to all others in meeting these objectives. Systems vary from company to company, and the application of a system may also vary from acquisition to acquisition depending on the complexity of items and the requirements levied.

Despite the differences in details of various companies' quality systems, certain features will be included in all state-of-the-art quality systems. They will include a formal quality management structure, quality policy formation and deployment information, and the traditional quality control and assurance functions (inspections, tests, etc.) as needed. The system will extend to all facets of a company's technical, support, and management processes and all parts of the organization. The system should be cost effective and should accommodate the present contract and circumstances. Methods for root cause identification of defects and elimination of those causes, and continuous improvement techniques should also be a part of all quality systems. Internal management audits should be performed by independent quality auditors and used to help management understand how well processes are performing throughout the organization. This isn't to say that quality professionals should be nothing more than a police function, but rather they should be helping to solve problems they help identify and effecting needed improvements. Quality assurance organizations exist to support the rest of the organization – helping everyone do their jobs better for the good of the entire organization. The concept of internal customers should be well understood by modern quality professionals.

Modern quality organizations should be charged with the following responsibilities:

- Determining how well systems and processes are working.
- Ensuring that functions and product/process teams are effectively integrated.
- Training of personnel in the use of state-of-the-art quality tools and techniques.
- Helping to deploy these tools and techniques.
- Helping to develop new processes.
- Ensuring implementation of root cause analysis in the problem solving process.
- Identifying improvement opportunities in all company processes, including management, engineering, manufacturing and support processes, helping to develop feasible improvements (rather than just telling others that they need to improve), and helping to implement the improvements.

The personnel in modern quality assurance organizations should be experts in state-of-the-art quality systems. They should be as involved with IPPD teams in the earliest phases of the development process and throughout the product life cycle as required to maintain a continuous awareness of the status of the work being performed. They should always be available to the IPTs for consultation. Depending on the circumstances, the traditional role of independent inspector/tester quality personnel may still be necessary, but the main focus should be proactive support rather than reactive policing. In other words, quality personnel should provide the quality tools and quality perspectives needed to support the personnel who are directly adding value to the product, rather than distributing notifications when they discover nonconformances. Recommended work statement content for the over-arching state-of-the-art quality system is provided in subsequent subsections and is in accordance with JACG guidance. It is recommended that a discussion of the overarching quality system requirements be included in the RFP technical section under the evaluation factors for award.

6.4 Recommended RFP/Proposal Content

6.4.1 Government Statement of Objectives (SOO)

- The government's objective is that the contractor implement an overarching quality system that ensures effective execution, integration, and administration of the design, manufacturing, and deployment processes and systems needed to manage risk and ensure achievement of all performance requirements.
- The system should be implemented within the context of a foundational quality management system, and should be designed to prevent the production of defective product.
- The system should also include a means for measuring the effectiveness and ensuring the continuous improvement of systems and processes.

6.4.2 Contractor Statement of Work (SOW)

- The contractor's SOW should address how a state-of-the-art quality system will be deployed within the context of existing quality management systems to prevent the production of defective products.

- The contractor's SOW should specify the means which will be used for measuring the effectiveness of the quality system, and for ensuring the continuous improvement of systems and processes.

6.4.3 Integrated Master Plan (IMP) Exit Criteria

Exit criteria will be addressed as part of the specific practices sections in subsequent chapters.

6.4.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

6.4.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- The offeror's quality systems should be described in the proposal to confirm that a formal, systematic approach is in place to assure product quality.

- The offeror's proposal should address the processes and procedures which will enable the manufacturing engineering and quality engineering functions to participate fully in the IPT.

- The test and evaluation program should reflect the incremental verification of objectives throughout the design cycle.

- The offeror should provide for government insight into the quality program and should flow down this insight process to suppliers.

- The proposal should reflect the offeror's plans for using commercial or industrial standards in place of government specifications, and the strategy for implementing these standards with suppliers.

- The offeror should incorporate the quality system elements of the proposal into the final contract.

6.4.6 Evaluation Criteria Guidance (Section M)

The quality system proposed by the offeror will be evaluated on the extent to which it provides assurance of the offeror's ability to prevent the production of defective products. Proposed systems should provide for:

- Ensuring effective management of identified risks.
- Integration of technical and management processes and systems.
- Measurement of the effectiveness of processes and systems.
- Continuous improvement of processes and systems.
- Training personnel in the use and deployment of state-of-the-art quality tools and techniques.

7. PRE-EMD PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

7.1 Introduction

The purpose of the Manufacturing Development Guide (MDG) is to promote the development of effective, affordable weapon systems through the use of best business practices that support acquisition reform initiatives in general. In order to fully realize the long-term program benefits available through utilization of the practices described in the MDG, it is essential that the practices be implemented as early in the program life cycle as possible. A pre-requisite for effective implementation of the MDG practices is the participation of the manufacturing engineering (ME) function in the early development of the IPPD process. The large number of MDG practices that fall under the manufacturing umbrella functionally, as shown in Figure 7-1, should emphasize the necessity of manufacturing engineering participation.

During the Pre-Engineering and Manufacturing Development (Pre-EMD) program phases, the MDG objectives are met by encouraging the early, active participation of manufacturing engineering in the product development cycle and by stressing the importance of production cost as a high priority product design requirement. The focus of this chapter is the role of manufacturing engineering in pre-EMD Integrated Product Teams (IPTs) and in the early product development process. Emphasis is placed on evaluating the manufacturability and associated process capability of design options, so that production risk and cost can be appropriately traded off with system performance. In addition, the foundation of defect prevention techniques is laid in preparation for further implementation in the EMD and Production phases.

To ensure that affordability and manufacturing issues are fully addressed during the acquisition process, government personnel at the System Program Office (SPO) may wish to use the Contract Data Requirements List (CDRL) and Proposal Instructions to Offerors (PIO) guidance subsections in generating RFPs, and the Recommended RFP/Proposal Content, Integrated Master Plan (IMP), and Evaluation Criteria guidance subsections in evaluating contractor responses. Contractors, in turn, should be encouraged to review the contents of the MDG for guidance in preparing the affordability and manufacturing sections of their proposals.

These Pre-EMD RFP Guidelines are intended to achieve several objectives. (1) Identify the program technical requirement in order to fully implement manufacturing concepts in the Concept Exploration (CE) and Program Definition and Risk Reduction (PDRR) phases of a program, and to implement IPT approaches. (2) Elaborate on the role and responsibilities of manufacturing engineering for the development IPT. (3) Identify the attributes of a defect prevention system under which these concepts could be fully implemented. The guidelines provide discussions of the following topics:

- Production Cost Modeling
- Manufacturing Capability and Risk Reduction
- Key Suppliers

- Key Characteristics and Processes
- Variability Reduction
- Virtual Manufacturing.

The functional relationships of these practices is shown in Figure 7-1.

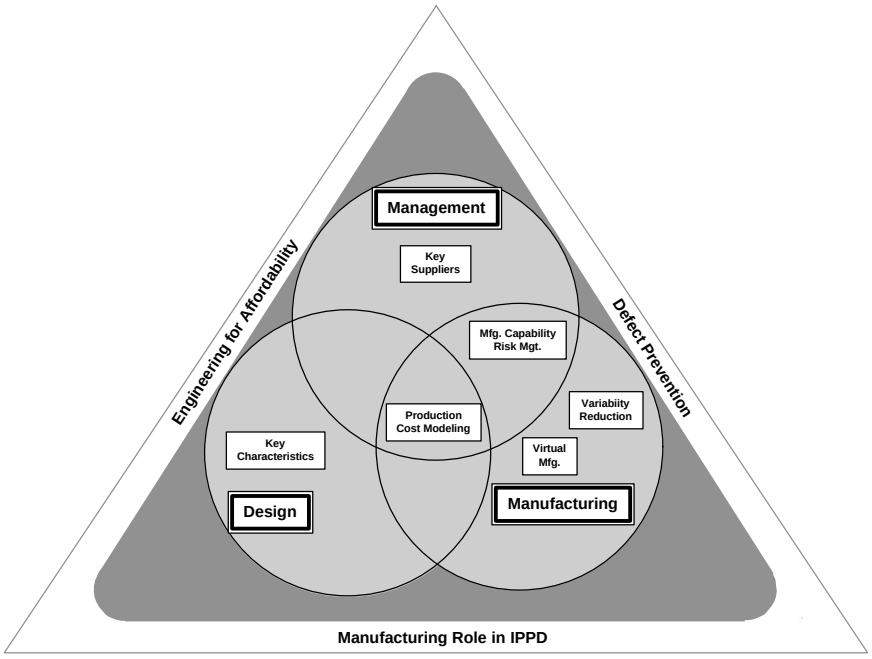


Figure 7-1. Functional Mapping of Pre-EMD Practices

In each of these subsections guidance is provided on Statement of Work (SOW) content, IMP exit criteria, and PIO and evaluation criteria (Sections L and M). In all cases the suggestions should be evaluated and applied as appropriate for a specific program.

7.1.1 Suggested Pre-EMD Statement of Objectives (SOO) Content

Manufacturing Development. The government's objective is that the contractor implement those processes and systems that consider manufacturing, quality, and design functions in achieving a balanced design solution which meets cost, schedule, and performance requirements with acceptable risk. The following may be considered as appropriate practices for implementation: identification of key characteristics and processes; variability reduction on product, process, and infrastructure; electronic simulations of the manufacturing environment; cost modeling and Cost As an Independent Variable (CAIV); the use of IPTs; and relationships with key suppliers.

7.2 Production Cost Modeling

7.2.1 Introduction

In an Engineering for Affordability environment, earlier and increasingly accurate Production Cost Modeling becomes extremely important. The Production Cost Model (PCM) should be developed and used in conjunction with system performance and effectiveness simulations so that the cost impacts of design alternatives can be quickly evaluated. The PCM should be continuously refined as the design definition improves, and should provide the basis for the production cost requirement that will be established for Engineering and Manufacturing Development (EMD). This cost requirement is often an Average Unit Production Price (AUPP). Chapters 3 and 5 provides additional information on cost requirements.

Figure 7-2 shows how this practice area integrates with subsequent practices in the MDG framework.

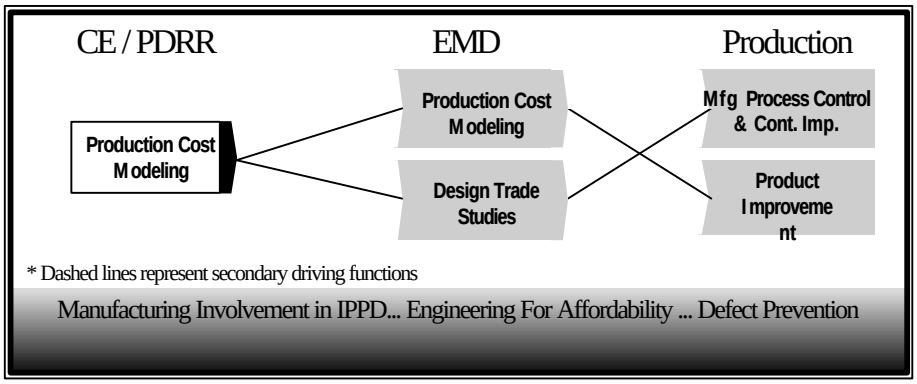


Figure 7-2. How Production Cost Modeling Integrates with Subsequent Practices

7.2.2 Rationale

The need for significantly more affordable Department of Defense (DoD) programs in a limited budget environment has created a need to better understand the cost impacts of design decisions during initial system development. Validated cost modeling tools are essential for conducting the cost and performance trade studies that are needed to make informed design decisions.

The PCM will also play a key role in assessing the overall progress of the development program. Current cost estimates and trends at Integrated Master Plan (IMP) milestones, plus the status of current and planned cost risk abatement efforts, will become a part of the determination of whether to proceed to the next phase.

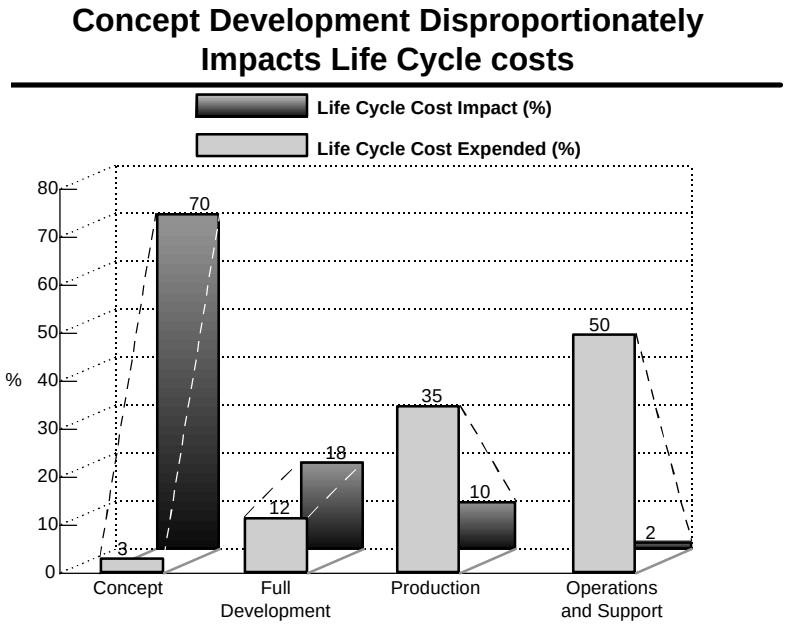
7.2.3 Guidance

Accurately modeling production costs with high fidelity during the pre-EMD development activities is extremely difficult. This is because inputs to the PCM and production cost estimates, initially calculated as rough order of magnitude (ROM) estimates, will evolve throughout the Pre-EMD phase activities. At all times, however, they should reflect the best possible estimates based on current development status, and they should serve to identify those cost issues that need to be addressed by formal mitigation activities. Preliminary government validation of the Production Cost Model should occur during Program Definition and Risk Reduction (PDRR), with final validation and delivery of the model at the end of EMD.

Many commercial cost models are available for use and/or adaptation to fit company-unique accounting systems . The level of detail and the complexity of the cost models appropriate for a product will vary depending on the product's complexity, the program size, and related factors. In order to perform real-time cost and performance trades efficiently, cost models should be linked to the performance simulations used for evaluating the technical merit of potential designs. The PCM established for the baseline system concept should be refined as the concept develops. The objective is to predict the program cost impact of production rate and delivery schedule variations, and to provide a projected production cost for evaluation against the production cost requirement upon entering EMD. On some programs, a Life Cycle Cost Model may be required for projecting support, maintenance, spares inventory, storage, and disposal costs. As discussed in Chapter 5, cost partitioning may be used to provide a framework for the final production cost model.

7.2.4 Lessons Learned

Studies have repeatedly shown that the best opportunities for system cost reduction occur during early program development phases (Figure 7-3). The early initiation of production cost modeling supports cost reduction activities by helping to identify the areas with the greatest potential for payback.



Source: **Producibility Measurements Guidelines**, NAVSO P-3679, Dept. of the Navy, August, 1993

Figure 7-3. Impact of Early Activities on Life Cycle Cost

As noted in Chapter 5, previous experience with Design to Cost (DTC) approaches has been disappointing. In many cases, the ground rules and assumptions that fed production cost models (rate, volume, schedule) were not updated to reflect program changes and so the production cost estimates produced by the DTC activities had no validity. To be effective and credible, the Production Cost Model must be validated, maintained, and kept up to date with all program ground rules and assumptions.

7.2.5 Recommended RFP/Proposal Content

7.2.5.1 Government Statement of Objectives (SOO)

See Chapter 7, Section 7.1.1 "Suggested Pre-EMD Statement of Objectives (SOO) Content."

7.2.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss in submitted SOWs the topics listed below, to the extent that they are applicable to the offeror's proposed program:

- Ground rules and assumptions of the PCM.
- Validation and configuration control of the PCM.

7.2.5.3 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program):

- Preliminary production cost estimate documented, including back-up calculations, ground rules, assumptions, and rationale.

Milestone II (Approval to Enter EMD):

- Preliminary production cost model (PCM) validated by government.
- Updated production cost estimates documented.

7.2.5.4 Contract Data Requirements List (CDRL) Guidance

The primary products of this effort will be the Production Cost Model and production cost estimates. Delivery of PCM documentation will be dependent on program direction and requirements. If the government takes delivery of this data, it will assume administrative costs for data maintenance. Data will be maintained, updated, and presented by the contractor for Data Update Events (DUEs). Documentation maintained by the contractor will provide a clear trail for audit and verification purposes.

Suggested CDRL Content:

- No formal CDRLs are suggested for this section.
- (DUE) Production cost estimates at all milestones and program reviews.
- (DUE) Preliminary PCM available ___ days prior to Milestone II for government approval/validation.

7.2.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for development and validation of the Production Cost Model.
- Processes for development and validation of production cost estimates.
- Data pertaining to use and performance of PCM on previous programs.

7.2.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Production Cost Modeling practices should be based upon:

- Demonstrated processes for development and accuracy of cost models.

- Demonstrated processes for development and validation of production cost estimates.
- Experience on previous programs related to use and performance of PCM.

7.3 Manufacturing Capability Assessment and Risk Management

7.3.1 Introduction

The manufacturing capability assessment and risk management effort is a structured, disciplined approach to evaluating available and forthcoming manufacturing capabilities in order to identify and assess risk early in the design process. (Risk is defined as any factor which could cause a program not to achieve a goal, objective, or performance requirement, or not to stay within cost and schedule constraints.) The IPT can then develop and execute risk mitigation plans in order to maintain an acceptable level of risk throughout the acquisition program and the product life cycle. In the past, designers often did not consider technology maturation issues and the associated risks until the demonstration and validation effort, or even later.

One source of risk, for instance, is the selection of materials which will require new processes, immature processes, or low-yield processes for which manufacturing capabilities have yet to be developed. The active participation of manufacturing engineering early in the IPPD process is intended to reduce the risk of transition to production and to reduce total program cost through the avoidance of engineering changes and rework later in the program. A prerequisite, however, is a clear understanding of the relationship between manufacturing capabilities and the associated costs of achieving a producible and affordable design.

Because weapon system acquisitions so often include multi-company teams and multiple subcontractors, the capabilities of teammates and preferred suppliers must also be taken into consideration in the risk management effort. The integration of GFP contractor risk management programs is essential too.

While risk is called out separately here in order to emphasize specific concerns related to manufacturing, manufacturing risk should always be fully integrated into the program-wide risk management effort. (This in fact is one of the key responsibilities of the manufacturing engineering representative on the IPT in the pre-EMD phases.) The principles set forth in this section should therefore be considered as continuous with the program management risk sections in the RFP, as well as with Systems Engineering and other relevant sections of the RFP. Design trade studies and requirements verification efforts will be the source of much of the risk identification and assessment.

Figure 7-4 shows how this practice area integrates with subsequent practices in the MDG framework.

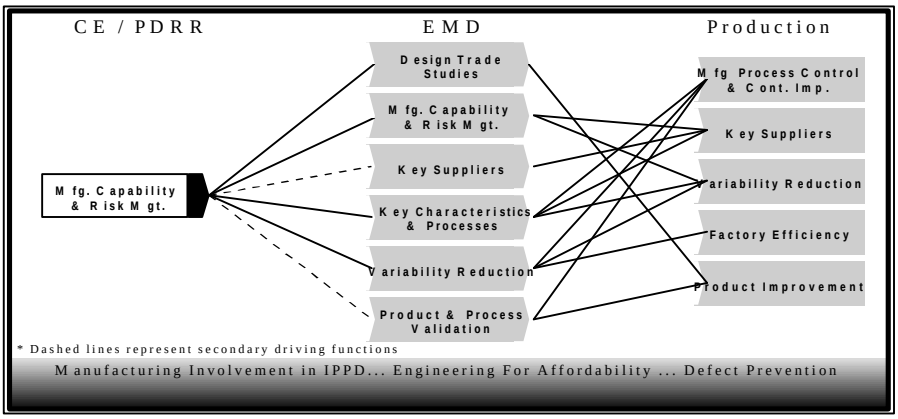


Figure 7-4. How the Manufacturing Capability Assessment and Risk Management Practice Area Integrates with Subsequent Practices

7.3.2 Rationale

The reduction of risk associated with manufacturing, transition to production, and final product cost must start with active manufacturing engineering participation on the integrated product team. Recognizing that a high percentage of program cost is "locked in" by decisions made during the very early phases of an acquisition program leads to a real appreciation of the importance of a balanced, integrated product team, one including all team members and preferred suppliers in the CE and PDRR phases.

From an affordability perspective it is generally accepted that the design features should reflect current rather than future process capabilities. The advantages of new materials and processes that offer weight, performance and cost benefits must certainly be considered, but the management of the cost, schedule and quality risks associated with new materials and processes must be included in the consideration. These elements must also be balanced with the issues of sustaining industrial base readiness and key capabilities within an austere acquisition environment.

7.3.3 Guidance

The contractor should demonstrate a formal process for identifying and managing risks associated with the manufacturing capabilities of the team and the preferred suppliers who will participate in the program. In the CE and PDRR phase the risk management effort should identify new materials and processes required *throughout* the supply chain. The risk management process should also provide performance metrics on known design features and processes, and on the relative capabilities of the team and its preferred suppliers to place the work to be performed in the best location.

In particular, manufacturing risk in the CE and PDRR phases focuses on using the IPPD process to anticipate areas of cost and schedule risk, and establishing appropriate risk reduction efforts. The Program Office should tailor the RFP to address the industrial base sustainment issues which are to be included in contractor proposals. However, the fundamental responsibility

for recognizing key component capacity constraints and providing adequate risk mitigation rests with the contractor. Contractors should be encouraged to identify the Internal Research and Development (IRAD) efforts and internal investments in materials and processes which are part of the risk mitigation effort for new acquisition programs.

An example of a formal approach to identifying and managing risks associated with manufacturing capabilities and technology maturation issues is provided by the Joint Strike Fighter (JSF) Manufacturing Capability Assessment Tool Set (JMCATS). JMCATS is a computer-based tool set specifically developed to guide an IPPD team through assessments of the manufacturing capabilities required by a program. It provides a structured approach for documenting manufacturing and design options and decisions. JMCATS supports an iterative manufacturing capability assessment process which allows requirements to be reallocated when it is determined that the manufacturing capability risk is too high. Other risk management tools and concepts have been developed by both government and commercial interests. These include Manufacturing Capability Assessments (MCA), a Manufacturing Capability Requirements Assessment (MCRA) process developed by the Engineering Directorate of the Air Force Material Command (AFMC/EN); an Integrated Risk Management (IRM) process developed by the Air Force Aeronautical Systems Center (ASC); and pre-control concepts for risk management at the individual process level. For basic information and bibliographical information, see *Juran's Quality Control Handbook*, Fourth Edition, Section 24.

7.3.4 Lessons Learned

In the defense acquisition environment, risk has often become an issue whenever the contractor/government acquisition team overestimates technology readiness, downplays potential transition to production problems, or fails to plan and perform effective risk management. The results frequently have included cost overruns, schedule delays, and technical compromises. Initial impacts surface as early as PDRR and continue throughout succeeding program phases.

The importance of starting as early as possible prior to EMD in identifying potential manufacturing risks has been shown repeatedly. It is important to identify parts with high manufacturing risk in Pre-EMD and to develop a process development/validation program for full scale parts in EMD prior to creating a Build-to Package.

A classic lesson learned example is provided by a close air support aircraft program from the mid-1970s in which the adverse consequences of not identifying and managing manufacturing capability risk had serious consequences. It was discovered subsequent to source selection that the prime contractor was lacking in both manufacturing capability and the capacity required to satisfy production aircraft delivery schedules. The Air Force itself ultimately had to furnish a significant quantity of machine tools and related production equipment to help resolve the shortfall.

This experience led to the establishment and institutionalization of Manufacturing Management/Production Capability Reviews (MM/PCRs), conducted as an integral part of the source selection process. The first major MM/PCR was performed in concert with the Air Combat Fighter (later designated F-16) source selection in 1976. Positive MM/PCR results

included not only the generation of critically needed inputs to Source Selection Evaluation Boards (SSEBs) and Advisory Councils (SSACs), but also led to greatly increased defense industry attention to production planning.

Early consideration of production issues in the Concept Exploration and PDRR activity phases is a key contributor to the lowering of risk at transition to production. A formal, disciplined risk management effort that is integrated into the overall program risk management plan (along with the early recognition of constraints associated with limited capacity, industrial base sustainment issues, and manufacturing capability issues) is essential to cost, schedule, and quality performance. That all these constraints are addressed is assured by the active participation of manufacturing engineering in the earliest IPT activities, and is formally documented as part of the IPPD procedures.

7.3.5 Recommended RFP/Proposal Content

7.3.5.1 Government Statement of Objectives (SOO)

See Chapter 7, Section 7.1.1 "Suggested Pre-EMD Statement of Objectives (SOO) Content."

7.3.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- How IPPD procedures used in the CE and PDDR phases will apply to process and production capabilities.
- Risk mitigation strategies for material and process issues.
- Risk mitigation efforts which involve the building of virtual or physical prototypes of components.
- Concurrent development of ST/STE and SE as a schedule risk reduction procedure.
- Production capability or capacity issues, industrial base sustainment plans, and foreign-sourced materials.
- IRAD and internally funded activities which apply to the reduction of risk for the program, including a brief description of the technology, expected results, and schedule.
- The metrics used for evaluation of producibility and related cost impacts in the design trade studies, including those of key suppliers.

7.3.5.3 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program)

- Materials lacking mature processes identified for manufacturing risk management purposes.
- IRAD and other programs established to reduce risk.
- Manufacturing capability database architecture defined.
- Manufacturing capacity issues identified.
- Industrial base sustainment issues identified.

Milestone II (Approval to Enter EMD)

With the Manufacturing Capability Assessment completed and risk mitigation initiatives planned, key areas addressed include:

- New and/or environmentally questionable materials and processes included in program risk management planning.
- Contributions of IRAD and other independently funded programs factored into program schedule.
- Manufacturing capability database includes all technologies applicable to identified Key Characteristics.
- All risk reduction activities factored into program schedule.
- Industrial facilities and manpower requirements planning included in IMP.
- Industrial base sustainment issues included in IMP.
- Test requirements and test articles identified in IMP.

7.3.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

7.3.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following::

- Identification of new and environmentally questionable materials and processes.

- Environmental-related manufacturing risk factors incorporated into risk management planning.
- Identification of related issues outside the scope of this program, including funding sources such as IRAD, CRAD, and related contracts.
- Industrial capacity and industrial base sustainment issues.
- IMP reflection of risk management activities.
- IMS reflection of cost and schedule risk management activities associated with the time-phasing and stability of funding from other sources.

7.3.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to manage risk and assess manufacturing capabilities should be based upon:

- Identification of the databases and processes employed to assess the potential risk of qualifying new materials and proving immature processes.
- Proposed plans for addressing industrial capacity and industrial base sustainment issues.
- Reflection in the program schedule of areas of risk resulting from planned funding sources outside the immediate contract.

7.4 Key Suppliers

7.4.1 Introduction

Key supplier partnerships and strategic business alliances have become critical factors in today's defense system acquisitions. Partnerships foster joint commitments between companies and promote shared investments in product design and development. Resource sharing and mutually focused internal research and development activities result in aggressive, efficient problem solving and product development. It is not the intent of these guidelines to promote a business strategy of either exclusive partnerships or sustained competition. Rather it is to promote supplier participation in the program teaming structure and in proposal, development, and design activities as soon as the business strategy decision is made. This early supplier participation will allow the team to exploit complementary strengths, address weaknesses, and take mutual ownership of problems and solutions.

A key supplier, including suppliers of Government Furnished Property GFP, under the Manufacturing Development Guide (MDG) philosophy, is a supplier at any level whose performance in the areas of cost, schedule, or technical performance, is essential to the development and production of an effective, affordable system. There are several criteria that can result in a supplier being deemed key:

- If the requirements flowdown process, as shown in Figure 7-5, results in a supplier's "product characteristic" being essential to attaining the "system attribute requirement" then the supplier should be considered a key supplier.

- If a supplier is identified as "sole source" because of unique technologies or unique manufacturing capabilities, the supplier should be considered a key supplier.

- If excessive risk is a factor, either in cost or technical performance, with no low-risk alternative available the supplier should beconsidered a key supplier.

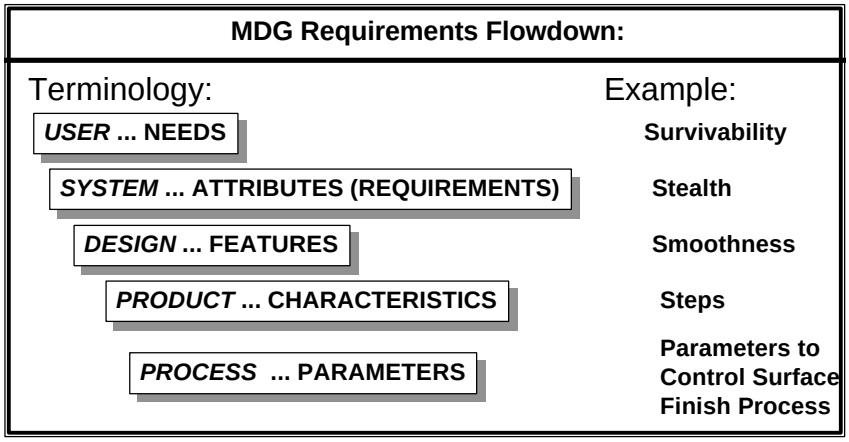


Figure 7-5. Requirements Flowdown Terminology

Figure 7-6 shows how this practice area integrates with subsequent practices in the MDG framework.

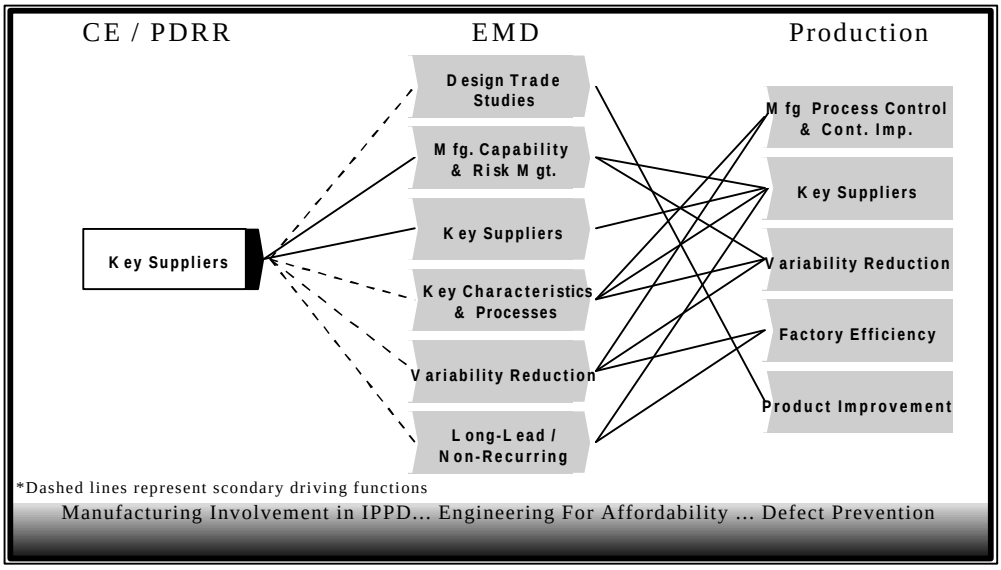


Figure 7-6. How the Key Suppliers Practice Area Integrates with Subsequent Practices

7.4.2 Rationale

Supplier performance becomes increasingly important as the percentage of weapon systems work performed at the supplier level continues to grow. Various studies have shown that, once a program reaches production, supplier activities typically account for more than 60% of the total production cost. Key suppliers are responsible for the full gamut of program activities involved in system acquisition. They perform design tasks, trade studies, risk management, key product and process identification, and they flow down authority to assure that their performance allocations are met. For these reasons it is essential to incorporate key suppliers into program planning and development as early as possible so they can participate in the allocation of requirements and design trades as well as resource sharing during the development and detailed design activities. Early identification of key suppliers will facilitate the efficient implementation of training and requirements flowdown.

7.4.3 Guidance

Key suppliers should be integrated into proposal preparation activities and should contribute to Integrated Product and Process Development (IPPD) early to enable the program to take full advantage of their product, system, and process knowledge. Supplier tasks must be fully integrated into the overall program plans and schedules and a plan should be developed which fully describes the supplier management effort. Successful supplier participation in the IPPD process requires effective communication of the requirements and goals by the prime contractor. It is intended that requirement flowdown be based on a cooperative agreement. The prime should have an established system for key supplier selection that bases the criteria for selection on past performance, proven abilities demonstrated on similar programs, and assessment of supplier

capabilities for the technology in question. The system also should address supplier implementation of the practices described in this Manufacturing Development Guide.

The use of Government Furnished Property, Equipment, Services, and Facilities (GFP) represents a special area of focus in the treatment of key suppliers. Communication and teamwork between the prime contractor and key GFP suppliers must be effective and continuous. This will require the Government to assure that its contracts with key GFP suppliers and the prime allow Associate Contractor Agreements (ACAs) which expedite communications in areas such as interface requirements, changes in design, risks, and schedules. Past programs have often been hampered by slips in delivery and integration problems when requirements and interfaces have not been effectively communicated to the key GFP supplier. The supplier management plan prepared by the prime contractor should address incorporation of key GFP supplier activities and schedules into the overall program plan. If an Associate Contractor Agreement is implemented on a program, the agreement must provide for the participation of key GFP contractors in IPPD arrangements and must allow adequate insight into key GFP contractor activities so they can be fully integrated into the Integrated Master Plan (IMP).

7.4.4 Lessons Learned

Programs that have not successfully integrated their key suppliers into the overall schedules and plans have commonly had difficulties in meeting their requirements and goals. Past practices often neglected the supplier base until after concepts had been developed and designs begun. This has led to problems where the supplier's product and process capabilities were insufficient to meet program needs. System integration has often been hampered by interface difficulties, and the prime contractor has often had little insight into supplier slippage and risk areas. Past performance data on supplier capabilities was often lacking or given less weight than cost in selection activities. Supplier performance lead times were often optimistically factored into overall program schedules without sufficient accounting for delays. Inadequate supplier risk assessment tools have often resulted in little risk identification and little subsequent mitigation planning.

7.4.5 Recommended RFP / Proposal Content

7.4.5.1 Government Statement of Objectives (SOO)

See Chapter 7, Section 7.1.1 "Suggested Pre-EMD Statement of Objectives (SOO) Content."

7.4.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Flowdown of the key characteristics and processes practice (see Chapter 7, Section 7.5, "Key Characteristics and Processes") to suppliers.

- Flowdown of key design features and key product characteristics (see Chapter 7, Section 7.5, "Key Characteristics and Processes") for which suppliers are responsible.

- Identification of key suppliers, including suppliers of GFP, and integration of supplier activities into the overall program plan.
- Early supplier participation in Integrated Product Teams (IPTs).
- Implementation of Associate Contractor Agreements (ACAs).
- Integration of key supplierevents/activities into the IMP.
- Identification, analysis and management of supplier risk.
- Integration of the supplier risk management plan into the program risk management plan.

7.4.5.3 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval to Begin Program):

- Key technology teams and strategic business alliances initiated.
- Key supplier risk assessment performed and manufacturing risk mitigation planning initiated.
- Flowdown of MDG practices to key suppliers initiated.
- Key supplier performance requirements flowdown and agreement established.

Milestone II (Approval to Enter EMD):

- Key process characteristics and key product characteristics flowdown initiated.
- Key supplier Manufacturing Capability Assessment (MCA) performed and results presented.
- Preliminary tolerance flowdown/error budget established.Preliminary EMD manufacturing plans for key suppliers established.
- Preliminary electronic manufacturing simulations by key suppliers identified.
- Associate Contractor Agreements finalized with key GFP suppliers.
- Risk assessment and events/activities for key suppliers included in Integrated Master Plan.

7.4.5.4 Contract Data Requirements List (CDRL) Guidance

- Government Furnished Equipment list

- Government Furnished Property list
- Government Furnished Facilities list
- Government Furnished Services list.

7.4.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Approach to identification of key suppliers, including key supplies of GFP, along with criteria used to make the determination.
- Approach to integration of key supplieractivities into the overall program plan, including descriptions of the tasks involved, and events, with exit criteria, to be tracked to assure that supplier activities support overall program performance.
- Performance specification, key process, characteristics and key product characteristics flowdown.
- Past performance data relative to management of key supplier schedules and involvement of key suppliers in IPT activities
- Data pertinent to key supplier past performance in areas such as manufacturing capabilities, use of defect prevention techniques, customer satisfaction, and schedule adherence.
- Data to be collected and analyzed on the present program.
- Approach to integrating the risk management effort for key suppliers with the program risk management effort.

7.4.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- Defined criteria for the identification of those suppliers who are key.
- Disciplined, structured processes used for the integration of key supplier events/activities into the IMP and for requirements flowdown.
- Effective performance specification, key process characteristics and key product characteristics flowdown processes.

- Evidence of past performance in the management of supplier schedules and the involvement of key suppliers in IPTs.
- Key supplier experience in (or training plan for) the use of defect prevention processes and techniques.
- Key supplier past performance in cost, schedule, quality, and customer satisfaction areas.
- Data collection and analysis planning.
- Key supplier risk assessment and risk abatement plans.

7.5 Key Characteristics and Processes

7.5.1 Introduction

The identification of key product characteristics and their design limits, and the identification and determination of key production process capabilities, are basic engineering tasks which support manufacturing development. The objectives of this practice are to: (1) identify those product characteristics of the design which most influence operational performance;(2) support the mapping of product characteristics to production processes; (3) enable the balancing of product design requirements with manufacturing process capabilities; and (4) enable the development of the required process controls for production.

Figure 7-7 shows how this practice area integrates with subsequent practices in the MDG framework.

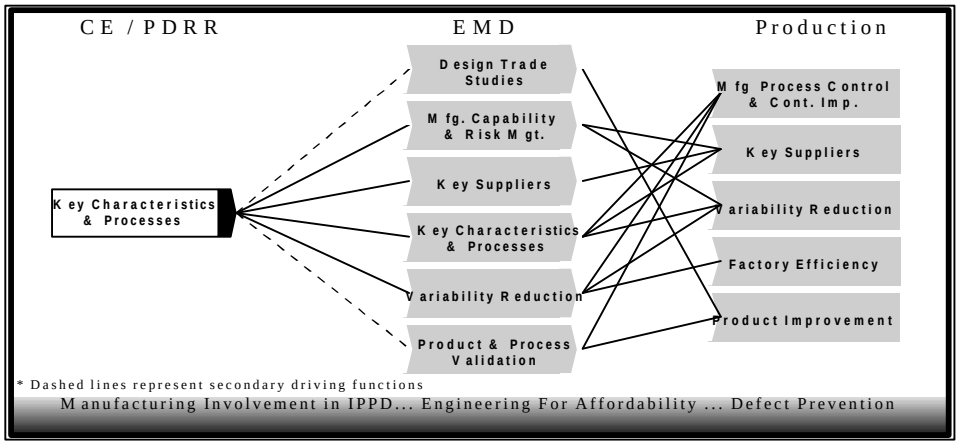


Figure 7-7. How the Key Characteristics and Processes Practice Integrates with Subsequent Practices

7.5.2 Rationale

The practice of identifying key product characteristics serves as an important communications tool during product development, design, and production. Key characteristics identification can serve many purposes in support of many different functions during Pre-Engineering and Manufacturing Development (Pre-EMD) phase activities. Among them:

- Identifying characteristics that should be traded with caution during trade studies.
- Identifying characteristics that should be considered for redesign in order to achieve a more robust product design.
- Identifying characteristics against which the application of defect prevention based design tools, such as Geometric Dimensioning and Tolerancing, could be beneficial.
- Identifying characteristics for which manufacturing process capabilities should be assessed (see Chapter 7, Section 7.3 “Manufacturing Capability Assessment and Risk Management”).
- Identifying candidate characteristics for future variability reduction activities (see Chapter 7, Section 7.6 “Variability Reduction”).
- Identifying the product characteristics that are most important and that may require extra attention in the manufacturing process, such as statistical process control techniques.

Identifying product characteristics and associated processes that should be addressed in the risk assessment and risk management planning activities.Identifying and qualifying key production processes should serve to make the transition to production smoother so that subsequent process improvement efforts can be directed to control of cost and quality.

7.5.3 Guidance

Key characteristics identification should begin in the initial Concept Exploration (CE) phase and continue throughout the Program Definition and Risk Reduction (PDRR), EMD, and Production phases of a program. Identification of key characteristics early in the design process provides a means to identify critical production processes before committing to designs, production equipment, and test equipment. However, implementation at any stage of the program provides a mechanism for improving the product performance, affordability, and quality.

The practice of variability reduction (see Chapter 7, Section 7.6 “Variability Reduction”) should be implemented in coordination with a key characteristics identification effort to improve fit, performance and service life of the product. As discussed in Section 7.6, and illustrated in Figure 7-8, embracing the concepts of variability reduction requires a change in thinking from "all products which are within the specification limits are equally good" to "products near the target value are better than products near the specification limit."

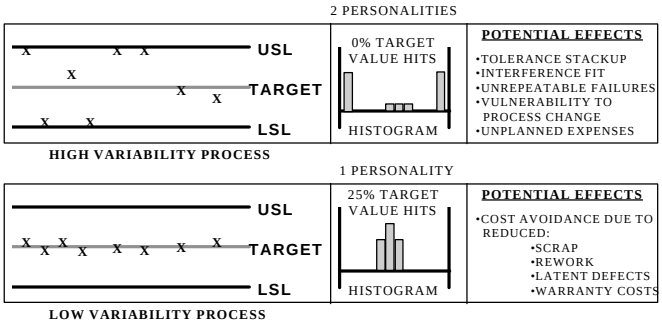


Figure 7-8. High vs. Low Variability Processes

The key characteristics identification process is best implemented in an Integrated Product Team (IPT) environment. It requires effective internal flowdown and total supplier involvement. A documented method for the identification of key characteristics, such as the use of Pareto and/or Quality Function Deployment (QFD) techniques (see Chapter 4, Manufacturing Engineering's Role in IPPD) should be established that considers the impact on product performance and the effects of product variability. An example of a tool which is useful in identifying key characteristics is the Loss Function method of assessing the loss (in either performance or dollars) resulting from a characteristic's deviation from nominal. This is shown graphically in Figure 7-9 (note that loss functions are not necessarily symmetric about the nominal, as shown in this example) One criteria that is often used is to declare a characteristic "key" if the magnitude of the slope of the loss curve is 1 or greater within the specification limits.

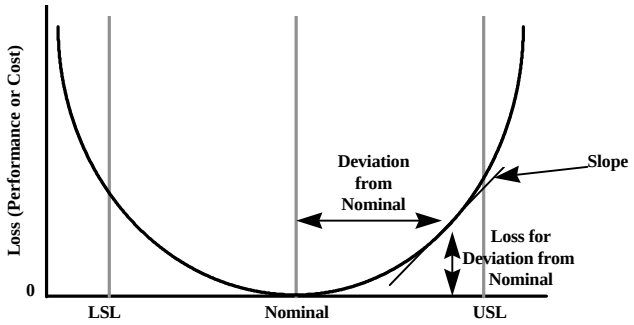


Figure 7-9. The Loss Function Method of Assessing Losses

Figures 7-10 and 7-11 demonstrate the top-level and detailed flows of the key characteristics identification process, and serve to establish the standardized nomenclature that will be used throughout this document.

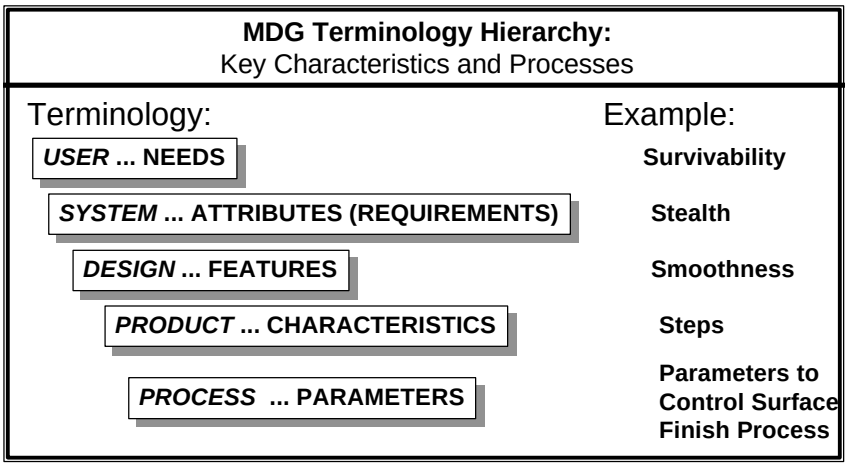


Figure 7-10. Key Characteristics Terminology

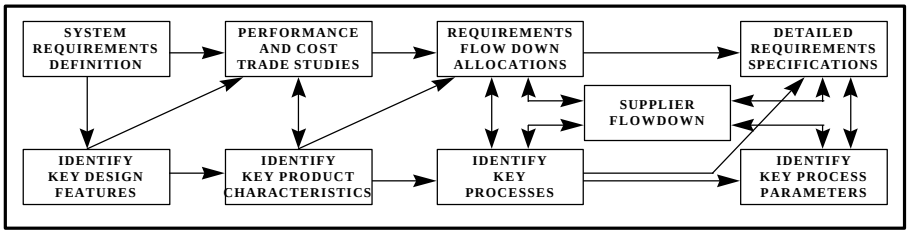


Figure 7-11. Key Characteristics Process Flow

The proper implementation of key characteristics must encourage changing the focus from the trivial many characteristics to a manageable set of the vital few characteristics (and related process parameters) whose control will provide the desired weapon system performance, affordability, and quality. Attention can then be given to these vital areas of product and process design in order to permit proactive steps toward the proper matching of process capability to product design requirements for the key product characteristics.

Key characteristics are identified conceptually, validated and then flowed to the responsible IPTs to be carried into the product and process documentation. Target values and tolerances are established as a part of rigorous error budget and tolerance flowdown analyses, in conjunction with process development to provide product/process matching. The key product characteristics are evaluated during the Manufacturing Capability Assessment and, if necessary, can be further addressed as part of variability reduction and manufacturing risk management activities. the effective flowdown of key characteristics and the key characteristics identification process to suppliers is essential to maintaining effective supplier communications and ensuring the success of future variability reduction activities.

The identification of key characteristics is a team effort requiring personnel familiar with the operational concept, system concept, system design, performance requirements, production

concept, and support concepts. Sensitivity analysis of key product characteristics to process variations may be performed and, if necessary, development tests may be performed to verify the relationships between key process parameters and key product characteristics. An easily audited documentation trail for the key characteristics identification process should be established and maintained throughout the program. Key product characteristics and key process parameters should be identified in the Technical Data Package, and in Build-To or Support-To packages through the use of a standardized Key Characteristic flag symbol.

7.5.4 Lessons Learned

The benefits of implementing defect prevention and manufacturing development tools and techniques have been well demonstrated at both commercial and defense-industry companies. However, the cost of doing so for some characteristics and associated process parameters outweighs the benefits received. The identification of key characteristics avoids the unnecessary implementation of Statistical Process Control and other variability reduction tools over the entire set of parameters associated with a production system.

For instance, the key characteristics identification approach provides a means of achieving variability reduction benefits without exceeding reasonable data gathering and tracking capabilities. As an example, a typical high rate production missile program may involve thousands of measured parameters, hundreds of in-house processes, hundreds of supplier processes, and hundred of units per week production rate. Attempting to apply variability reduction techniques to one hundred percent of the process parameters would require tracking and controlling millions of measurements per month. The use of statistical reporting methods coupled with the limiting of tracked processes/parameters to a “vital few” key product characteristics and process parameters is normally the most cost and schedule effective approach.

In the past, activities prior to entering the Production phase have been primarily oriented to the demonstration of product performance, with much less attention paid to the ability to consistently produce the required product characteristics in a cost effective manner. In many cases, the product designs have been completed, then turned over to manufacturing, which must attempt to optimize production implementation with existing plant capabilities. Little effort was expended during the pre-Production phases to address producibility. Process control is often not used and, in many cases, process capabilities are not known or not matched to product requirements. Mis-matches in design limits and process capabilities are discovered only in real time and under the pressure of delivery schedules. The resulting design or process changes are generally sub-optimal.

7.5.5 Recommended RFP/Proposal Content

7.5.5.1 Government Statement of Objectives (SOO)

See Chapter 7, Section 7.1.1 “Suggested Pre-EMD Statement of Objectives (SOO) Content.”

7.5.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Processes for identifying key product characteristics that most influence product performance, affordability, and quality, as appropriate to the level of design maturity.
- Documentation processes to ensure traceability of product key characteristics to the system requirements.
- Documentation processes for identifying key characteristics in design and process drawings and specifications.
- Tolerance flowdown process and error budget determination for key product characteristics.
- Methodology for balancing product key characteristic design requirements with the capability to maunfacture the product.
- Flowdown of key product characteristics and key process requirements to applicable suppliers.

7.5.5.3 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval to Begin Program):

- Key design features identified.
- Key Characteristics and Processes plan established.
- Identified product key characteristics assessed for process capability mis-matches and included in risk management plans.
- Process risk mitigation plans address process capabilities and the affordability implications of the processes being developed

Milestone II (Approval to Enter EMD):

- Preliminary key product characteristics identified.
- Preliminary key processes and parameters identified.
- Preliminary tolerance flowdow/error budget.
- Preliminary identification of verification methods.

- Supplier flowdown of product key characteristics and key processes established.

- Identified key characteristics assessed for process capability mismatches and included in Manufacturing Capability Assessment and risk management plans.

7.5.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

7.5.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Description of a design system process which identifies key product characteristics, key production processes, balances key product design requirements with the capability to manufacture the product, identifies proposed verification methods, and flows down key characteristics to key suppliers.

- Data pertinent to prime contractor and key supplier past performance in key product characteristics and key process identification.

7.5.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- The extent to which a disciplined, structured, and demonstrated process is used for requirements identification and allocation, identification of key product characteristics and key process parameters, and the achieving of balance between product design requirements and process capabilities.

- Evidence of prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

7.6 Variability Reduction

7.6.1 Introduction

Variability Reduction (VR) efforts during pre-Engineering and Manufacturing Development (pre-EMD) and EMD are intended to lay the foundation for continuous improvement in product quality and in manufacturing processes during the Production phase. The goals of these activities during pre-EMD are to: (1) determine the production processes which best match the product key characteristics; (2) verify the capability of those production processes; (3) develop the required process controls and infrastructure for production; and (4) enable the initiation of proactive efforts, such as manufacturing process development or product design trade studies, to

reduce production risk. The same discipline and effort should be applied to the qualification of the production processes as has historically been applied to verifying the performance of the product.

Figure 7-12 shows how this practice area integrates with subsequent practices in the MDG framework.

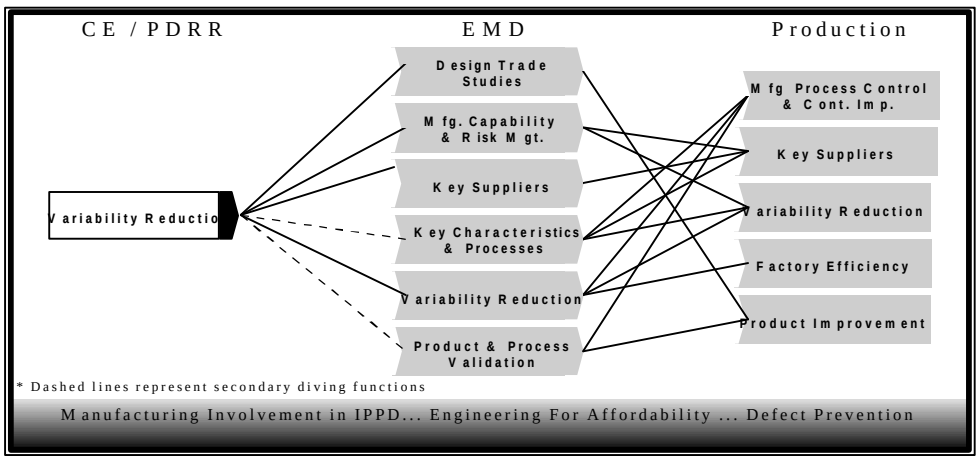


Figure 7-12. How the Variability Reduction Practice Area Integrates with Subsequent Practices

7.6.2 Rationale

Variability reduction is a systematic approach to reducing product and process variability in order to improve cost, schedule and performance. It is based on the concept that just falling within specification limits (goal-posting, pass/fail, attribute testing) is not the best measure of quality. Rather, the degree of variability of a key process and its relationship to design limits (process capability) becomes a measure of merit.

This benefits both the supplier and customer. For the customer of weapon systems which will be in the inventory for decades, the reduction in parts variability can reduce "infant mortality" problems, improve the performance of components and the overall weapon system, reduce spares and support equipment requirements during field introduction, lower repair costs, improve durability, and extend overhaul intervals. All of these improvements have a significant impact on reducing operations and support costs as well as improving operational availability and capability. For the supplier, the benefits are many: improved yields, reliable scheduling, reduced cycle times, reduced scrap and rework, better cost control, improved competitiveness, and improved customer satisfaction.

During pre-EMD phase activities, the VR emphasis is on gathering data and preparing the manufacturing infrastructure to support the Manufacturing Capabilities Assessment (MCA) (see Chapter 7, Section 7.3, Manufacturing Capability Assessment and Risk Management) and perform effective product/process matching in conjunction with the identified product key characteristics (see Chapter 7, Section 7.5, Key Characteristics and Processes). The availability of historical data on similar manufacturing processes, and electronic simulations of the

manufacturing environment (see Chapter 7, Section 7.7, Virtual Manufacturing) can greatly facilitate product / process matching. The matching of product and process during design is critical to avoiding costly product re-designs or unscheduled process developments in early production.

As illustrated in Figure 8-16 (Chapter 8, Section 8.8), a high variable process provides greater opportunities for failure and increases the likelihood of assembly problems. Even when the product assembly has been completed and acceptance tests passed, customers are often sensitive to the unit-to-unit variations in delivered systems that results from highly variable manufacturing processes. For example, two targeting systems may both meet specification but one may provide a clearer image, or more stable track point, and thus become identified as the customer standard for all systems. Any less capable systems delivered become a source of customer dissatisfaction and a potential for field returns simply because of the variation.

It is the goal of variability reduction, when enabled by the identification of key product characteristics, to reduce this unit-to-unit variation in delivered products by monitoring and controlling the minimum set of product key characteristics and associated process parameters during development and production.

7.6.3 Guidance

The first objective of pre-EMD variability reduction activities is to determine the production processes that best match the product characteristics. This product / process matching is performed in support of the Manufacturing Capability Assessment, and should be completed for at least those product characteristics that have been identified as key. Whenever possible, the MCA and product / process matching should be based on a measured historical database for the manufacturing equipment and processes available.

The results of this effort must be linked back to the manufacturing risk management planning and development efforts (Chapter 7, Section 7.3 “Manufacturing Capability Assessment and Risk Management”). Since a majority of the actual production on any system is accomplished by the prime contractor's suppliers, it is essential that all of these activities be implemented at the key supplier level as well.

The second objective of Pre-EMD VR is verifying the capability of the manufacturing processes which correspond to the identified key product characteristics. This process involves predicting the sensitivity of the product characteristics to changes in the key process parameters. Such predictions can be made by analyzing historical data, designed experiments, or other means. The identification of key process parameters provides the means for controlling the key product characteristics and final assembly performance variations. Each of the key process parameters will exhibit a natural variance, inherent in the manufacturing tools and process being used, that will result in variations in the associated product key characteristics.

These product key characteristic variations will propagate up through the assembly process to contribute to the performance variations observed in the final assembly. In order to eliminate undesirable variations in final assembly performance, the processes must be capable of producing

the product key characteristics with repeatable results. The manufacturing process for each key parameter should be identified in the manufacturing risk management plan, along with the status of the product / process matching. Product/process matching status is defined in terms of expected and / or obtained capability index, (C_{pk}).

The tolerance allocations for key product characteristics should be set in accordance with error budgets to meet the system requirements, which in turn will define the Upper and Lower Specification Limits for the key process parameters and are utilized along with the process mean and variability (3σ) in defining the C_{pk}. C_{pk} is computed as follows:

$$C_{pk} = \frac{\text{Minimum}[usl - avg, avg - lsl]}{3\sigma}$$

Where: *usl* = Upper Specification Limit

lsl = Lower Specification Limit

avg = process mean

3σ = process variability.

Higher C_{pk} values indicate a more capable process, with a C_{pk} of 1.0 indicating that the process has either its upper 3 sigma variation or its lower 3 sigma variation at the specification limit, as shown in Figure 7-13. A C_{pk} of 1.5 is equivalent to 6.8 defects per million opportunities, and represents a commonly encountered VR standard. A C_{pk} of less than 1.00 corresponds to a defect rate of greater than three per thousand. It is indicative of an immature or incapable process that should be addressed in the manufacturing risk planning activity or in design trades to balance the design with the capability to manufacture the product.

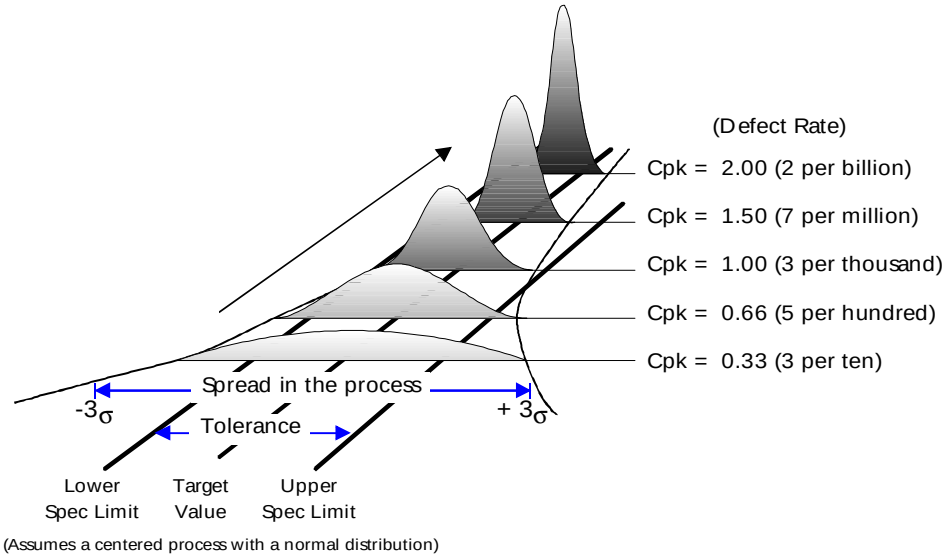


Figure 7-13. Capability Index

During the identification and implementation phase, actual product variability data may not exist. The capability of processes must be predicted based on the allocated tolerances and the expected process repeatability. Such predictions should be made for all process key parameters. In many cases, production data from similar products and processes will exist and can be used as a basis of prediction. For new, state-of-the-art product designs and manufacturing processes, best estimates must be made. As new virtual factory simulation capabilities emerge (see Chapter 7, Section 7.7), simulation results may be used to estimate process C_{pk}. Designed experiments can also be used to identify cost effective means for obtaining the data necessary to make the process capability predictions.

The third objective of Pre-EMD VR is to promote development of the required manufacturing process controls and infrastructure. This includes implementation of data collection and data reduction techniques that will be utilized in the EMD and Production phases to gather product and process-specific capability data and for the establishment and maintenance of a historical manufacturing process capability database to support future design trades, Manufacturing Capability Assessments, and variability reduction programs.

The fourth objective of pre-EMD VR is enabling the initiation of proactive efforts to reduce production risk. This can be accomplished by evaluating, as part of the manufacturing risk management activity, the capability index predictions described above. If the prediction indicates an acceptable C_{pk}, then the design and requirement allocations are matched to the available processes. If an acceptable C_{pk} is not predicted, either the requirements allocations, product design, or production processes should be changed.

During the early phases of a program, while modifying the product design and resulting processes is still a cost-effective option, the capability of the available processes should be evaluated and matched with the error budget/tolerance allocations for the product. In some cases,

either the state of the art or cost constraints may inhibit the meeting of the C_{pk} requirements and product re-design may be unacceptable. In those cases, an exception is made, and the process key parameter is carried as an accepted risk in the manufacturing risk management plan.

7.6.4 Lessons Learned

Experience has shown that VR represents a significant cultural change over historical practices. It has been successfully implemented through the formation of Integrated Product Teams (IPTs), at the assembly or subassembly level, with the responsibility for identifying and correcting production and design related problems. The effectiveness of using key product characteristics and process capability index data for product / process matching during the design effort in order to improve final design producibility has been demonstrated on many programs. In one case, the user need for lethality was flowed down to the forward and aft registration diameter key characteristics of mating subassemblies (Figure 7-14).

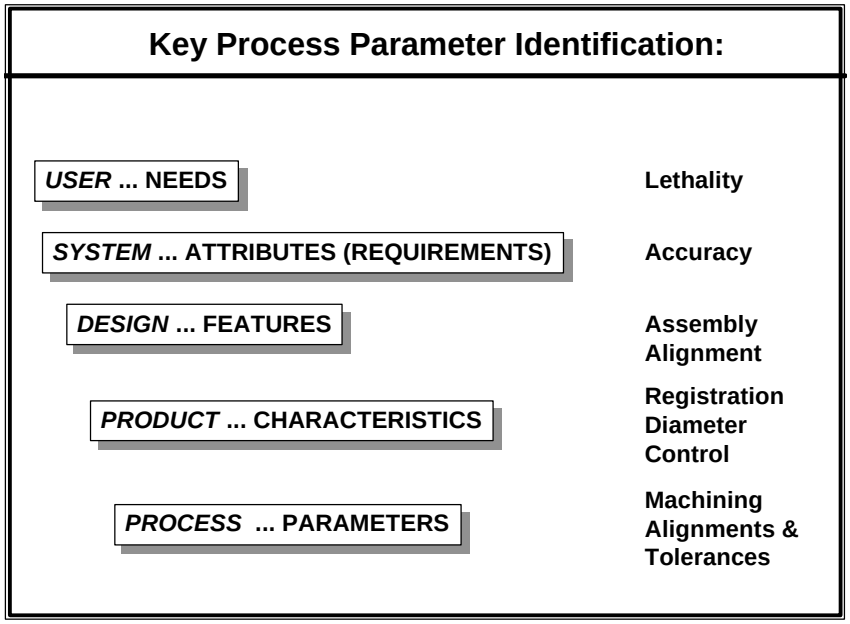


Figure 7-14. Identification of Key Process Parameters for VR Implementation

A Process Capability Assessment was performed to evaluate the producibility of each of the ten key characteristic dimensions using two potential manufacturing processes (A and B). The VR goal for the design was to achieve a C_{pk} greater than 1.50 for all parameters to guarantee a robust design. The resulting C_{pk}s for the original design, summarized in Figure 7-15, indicated that six of the ten key tolerances met the producibility goal, but that the other four could pose significant quality and reliability problems for both manufacturing processes. Since this assessment was performed early in the development program, the sub-assemblies affected were redesigned to incorporate more relaxed tolerances for four dimensions that were difficult to manufacture. The redesigned tolerances brought all the C_{pk}s (using Process A) up above the desired 1.50 level with no detrimental impact to system performance.

	Cpk for Process A	Cpk for Process B	Cpk level (VR Standard)	Cpk for redesign (process A)
Aft ID A	6	3.8	1.5	
Aft ID B	4.6	2.6	1.5	
Aft ID C	2.9	2.8	1.5	
Aft ID D	3	2.8	1.5	
Fwd Shoulder	2.8	2.9	1.5	
Tot. Runout	2.7	2.9	1.5	
Forward ID A	1.4	0.9	1.5	3.7
Forward ID B	0.8	0.4	1.5	1.6
Forward ID C	0.7	0.4	1.5	1.7
Forward ID D	0.6	0.3	1.5	5.2

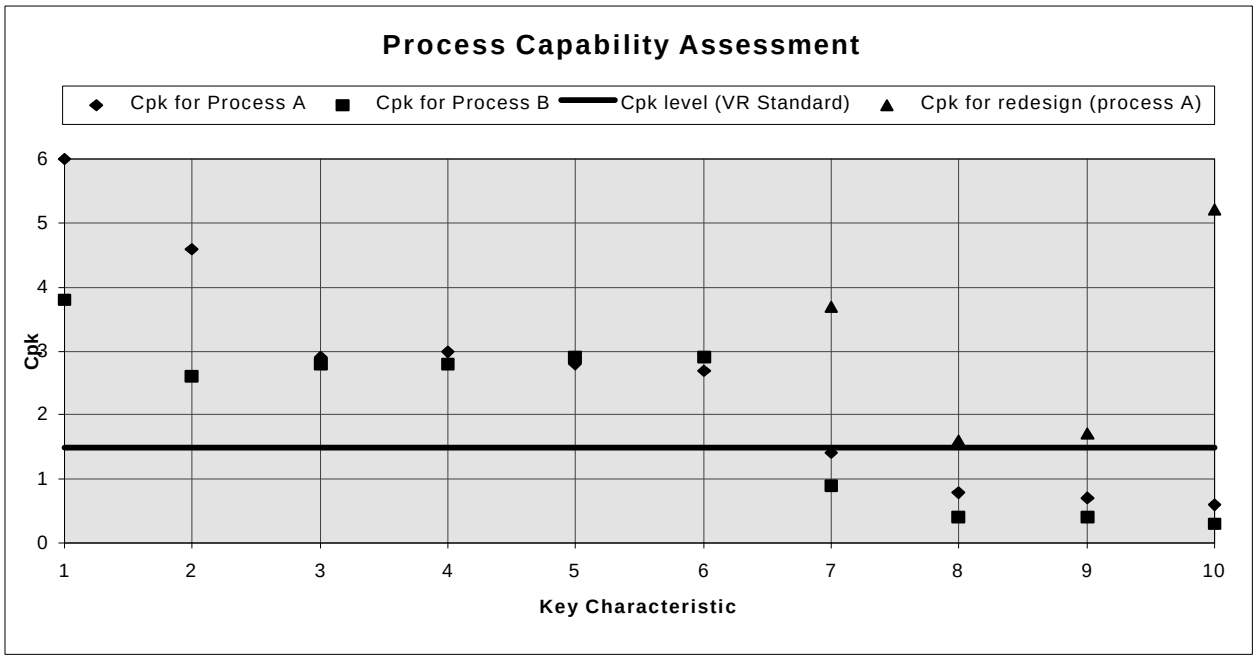


Figure 7-15. Capability Assessment Summary

Ideally, the contractor should have a VR process in place at the time of contract award, since an effective VR process represents a major cultural change and the full benefits may not be realized immediately. If the contractor does not have a VR process in place, introducing the concept as early in the program as possible will provide the maximum cost and schedule benefits. Full implementation of the VR process should ideally be complete by the time Low Rate Initial Production (LRIP) begins in EMD, but a VR program initiated at any stage of the product procurement cycle can be of great value.

It is not necessary for the government to contractually measure the contractor's VR process against a particular standard. Rather it is more important to verify that the contractor has an understanding of the overall intent, and that efficient processes are put in place to achieve the desired end result. This may require streamlining of the Configuration Control process to allow rapid responses, but enough discipline must be maintained to ensure the function and quality of the final product.

7.6.5 Recommended RFP / Proposal Content

7.6.5.1 Government Statement of Objectives (SOO)

See Chapter 7, Section 7.1.1 “Suggested Pre-EMD Statement of Objectives (SOO) Content.”

7.6.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror’s proposed program:

- Documentation and implementation of methodologies for evaluation of process stability and capability.
- Methodologies to be used for assessment of potential for quality improvements to the product design and production processes.
- Established and validated process control methods for data collection and data reduction.
- Documentation and implementation of methods to integrate VR activities with manufacturing risk management activities.
- Documentation of key supplier VR implementation.

7.6.5.3 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval to Begin Program):

Preliminary VR planning accomplished.Milestone II (Approval to Enter EMD):

- Planning for testing of key characteristics’ sensitivity to process parameter variation completed.
- Key supplier VR flowdown and training initiated.
- Preliminary integration of test/measurement errors into system error budget
- EMD phase VR planning completed.
- Process capability index developed for each product key characteristic.
- A process is designated for matching key product characteristic design requirements to process capabilities.
- Process control tools demonstrated and validated.

7.6.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

7.6.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the goals of this practice will be achieved, including the following:

- A description of the planned approach to variability reduction.
- Availability and planned utilization of defect prevention techniques and process control tools for controlling processes and assuring product quality.
- Metrics used to manage processes.
- Data on prime contractor and key supplier past performance in variability reduction, process control, and product / process matching.

7.6.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ variability reduction processes should be based upon:

- The merit of the planned approach to variability reduction.
- The planned utilization of defect prevention techniques and availability of established and validated process control tools and practices.
- The robustness of the planned metrics for managing processes.
- Evidence of prime contractor and key supplier past performance in variability reduction, process control, and product / process matching.

7.7 Virtual Manufacturing

7.7.1 Introduction

Virtual manufacturing is an integrated, synthetic manufacturing approach which uses modeling and simulation to address the full implications of the materials, production processes, tooling, facilities, and personnel issues involved in a new product's design and manufacture *before* the product and process designs are released and while changes can still be made. (In traditional product development approaches, by contrast, decisions made during the Concept Exploration (CE) and Product Definition and Risk Reduction (PDRR) phases have often locked 65% to 75% of the cost into the product, and have proven difficult or extremely expensive to change later.) Ideally, virtual manufacturing is used initially during Concept Exploration (CE) to evaluate the

producibility and affordability of proposed designs, and continues to be used through the EMD phase and into the Production phase with ever-increasing fidelity.

Product design iterations in a virtual manufacturing environment are often possible at a much lower cost and on significantly more accelerated schedules than in a physical environment. For these reasons, virtual manufacturing is becoming an increasingly common alternative or supplement to traditional means of demonstrating factory capabilities, such as Line Proofing. (See Chapter 8, Section 8.10, Product and Process Validation.) Like line proofing, virtual manufacturing supports risk management activities and verifies and validates the capabilities of the production facilities. But unlike line proofing, virtual manufacturing does not require actual production tooling and a first set of parts, and it builds virtual rather than actual products or product components.

Stereolithography is another rapid prototyping tool which can provide subscale or full scale physical model visualizations directly from CAD designs (and can allow assembly process demonstrations early in the design process). It can thus provide some of the benefits of simulation at a lower cost.

Virtual manufacturing approaches also enable the manufacturing engineer to effectively demonstrate manufacturing issues to the IPT. Because virtual manufacturing and virtual prototyping capabilities allow the integrated product team to validate its product design and production processes in a synthetic environment, the IPT can evaluate the performance characteristics of a greater variety of product configurations and make truly effective cost and performance trades at the very earliest stages of development. The result is an initial production unit which meets performance objectives with almost no rework and at the lowest possible cost.

Figure 7-16 shows how this practice area integrates with subsequent practices in the MDG framework.

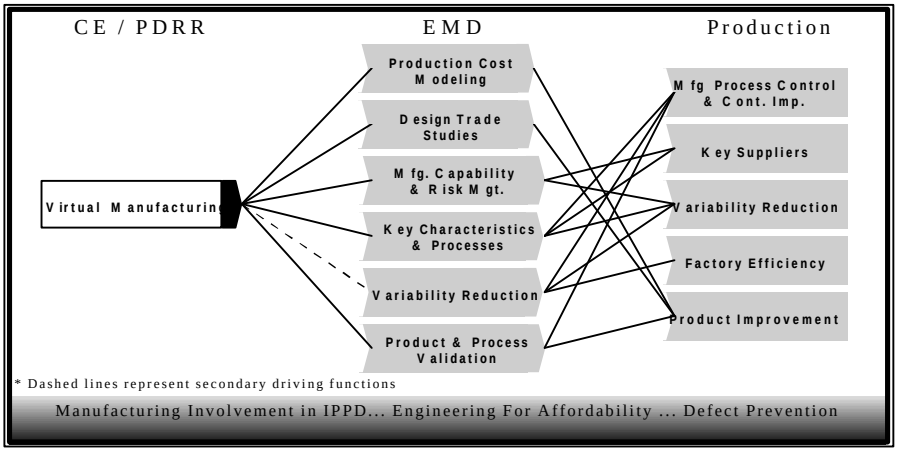


Figure 7-16. Integrating the Virtual Manufacturing Practice Area with Subsequent Practices

7.7.2 Rationale

The virtual manufacturing and virtual prototyping process includes new tools for assembly simulation, process flow simulation, and numerically controlled machine tool simulation. These are integrated with CAD tools, MRP, scheduling tools, time standards, work instructions, and planning. Virtual manufacturing activity starts with the development of a virtual prototype, and continues through the design and first unit planning phases to create a digital manufacturing plan. Addressing issues from plant layout to the supplier base, the digital manufacturing plan provides a solid foundation for manufacturing control protocols.

The benefits of virtual manufacturing include:

- Maturing the pre-EMD product and process design in a synthetic environment where changes can be made early and cost effectively.
- Increasing design iterations while decreasing physical iterations**.**
- Assuring optimum first time results for prototypes.
- Optimizing manufacturing planning and cost estimating.
- Enhances LRIP efficiency and facilitates ramp up to full production.
- Reducing the risk of transition to production.
- Reducing unit cost through the avoidance of rework.
- Reducing T_1 labor costs.
- Reducing sustaining engineering effort.
- Reducing production cycle time and verifying production tooling concepts.
- Producing simulations which are reusable for developing operator work instructions and maintenance tasks.

In essence, virtual manufacturing makes it possible to effectively realize for the first time the full benefits of the early involvement of manufacturing engineering in the IPT's conceptual development and design process. Before the advent of virtual manufacturing capabilities, the manufacturing engineer was a supporting presence on the integrated product design team. Now manufacturing engineering can be a fully involved function with effective tools that provide quantifiable results in the concept development and design process.

7.7.3 Guidance

The contractor should use virtual manufacturing tools to demonstrate that the product design developed during the pre-EMD efforts meets the cost and schedule objectives of the program.

This is best accomplished through preliminary production planning, which includes assembly simulation and process flow simulation, including the processes required for fabrication. These IPT efforts are led by the manufacturing engineering function during the pre-EMD phases. The contractor should also demonstrate the producibility of the proposed design through the use of virtual prototyping and virtual assembly, including 3D simulation of assembly for both the product and its proposed tooling.

Process flow simulation should identify the production resources required, including personnel skills, tool quantities, production space requirements, inventory levels, and resource constraints. This effort will serve to validate the cost estimates and proposed schedule performance. It will also identify issues associated with material availability or new process development. The simulation tools thus provide a quantitative and analytical basis for the participation of the manufacturing engineer in the IPT process.

7.7.4 Lessons Learned

The ability to assess manufacturing capabilities in a synthetic environment early in the design process has contributed to lower total costs, reduced technical and schedule risk in the transition to production, and increased confidence that programs can meet affordability targets. The effectiveness of one early implementation of virtual manufacturing was demonstrated on a major commercial aircraft program, which reported a 90% reduction in error related changes after the release of the product design.

Other companies employing virtual manufacturing processes for assembly simulation or visualization and process flow simulation report reduced total costs attributed to the schedule benefits and manpower savings associated with getting the design correct the first time. The combination of virtual manufacturing and integrated design and analysis tools already being developed and integrated by aerospace contractors has demonstrated a significant savings potential in comparison to traditional approaches.

A program to redesign an existing C-17 bulkhead, for instance, demonstrated the benefits of virtual manufacturing by comparing results to those of parallel activities using IPPD practices without VM. The design cycle time was reduced by 33%, and design cost was reduced by 27%. Another program, this one contractor funded, used solid modeling, parametric design, and virtual manufacturing tools to redesign a T-45 tail stabilator. EMD phase savings of 28% were achieved in comparison to the lower of two competitive bids using conventional design approaches.

In general, the application of IPPD approaches and other affordability initiatives on recent programs has been shown to produce reductions in EMD costs alone that range from more than 10% to as much as 25%. (EMD costs typically represent 13% of life cycle costs on a weapon system development program.)

7.7.5 Recommended RFP/Proposal Content

7.7.5.1 Government Statement of Objectives (SOO)

See Chapter 7, Section 7.1.1 “Suggested Pre-EMD Statement of Objectives (SOO) Content.”

7.7.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to address the topics below in their submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Preliminary manufacturing planning, virtual manufacturing, and virtual prototyping tools to synthetically demonstrate and validate program approaches.
- Virtual manufacturing to provide early links between design and manufacturing, and to facilitate performance trades.

7.7.5.3 Integrated Master Plan (IMP) Exit Criteria

Milestone I (Approval To Begin Program):

- Production concepts demonstrated through simulation.
- Cost objectives and affordability initiatives confirmed through simulation.

Milestone II (Approval To Enter EMD):

- Simulations demonstrate ability to meet producibility and affordability goals.
- Manufacturing risk areas included in simulations.
- Baseline established for EMD production activities.

7.7.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

7.7.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how achievement of the goals of this practice will be ensured, including the following:

- Virtual manufacturing, prototyping, and planning processes to be used in the pre-EMD program phase to ensure the effective early involvement of manufacturing engineering in the IPT design effort.
- Early involvement of virtual manufacturing tools to provide input to production planning and to production risk identification and management.
- Resources and experience needed to execute virtual manufacturing applications for the transition of the concept design into EMD and Production.

7.7.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ virtual manufacturing processes should be based upon:

- Demonstrated ability to manage risk through assembly simulation, process flow simulation, and process capability analysis.

- Demonstrated ability to evaluate manufacturing resource requirements and provide schedule credibility through process flow simulation.

8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.1 Introduction

The purpose of the Manufacturing Development Guide (MDG) is to promote the development of effective, affordable weapon systems through the use of "best business practices" that support the overall acquisition reform initiative. During Engineering and Manufacturing Development (EMD), these objectives are met by involving the manufacturing engineering function directly in the product design activities, particularly as a principal contributor to the cost/performance trades and manufacturing risk management processes. During this period key processes will be characterized and their stability and capability analyzed. Production capability will be evaluated and demonstrated, with the principle objective of reducing program risk at the start of production.

To ensure that affordability and manufacturing issues are fully addressed during the acquisition process, government personnel at the System Program Office (SPO) may wish to use the Contract Data Requirements List (CDRL) guidance and Proposal Instructions to Offerors (PIO) subsections of these guidelines in generating an RFP, and use the Work Statement, Integrated Master Plan (IMP), and Evaluation Criteria guidance subsections in evaluating contractor responses.

Main goals of the EMD phase RFP Guidelines are to: (1) identify the manufacturing-related technical activities that must occur during EMD to promote the development of an affordable weapon system and to reduce the program cost and schedule risks in transitioning to production; (2) elaborate on the role and responsibilities of manufacturing engineering in the EMD phase Integrated Process Teams (IPTs); (3) identify the attributes of a quality system under which these concepts could be fully implemented.

The EMD phase RFP guidelines provide discussions of the following topics:

- Production Cost Modeling
- Design Trade Studies
- Specifications and Standards Management
- Manufacturing Capability and Risk Management
- Key Suppliers
- Key Characteristics and Processes
- Variability Reduction
- Long Lead/Non-Recurring Activities
- Product and Process Validation.

The functional relationships of these practices are shown in Figure 8-1.

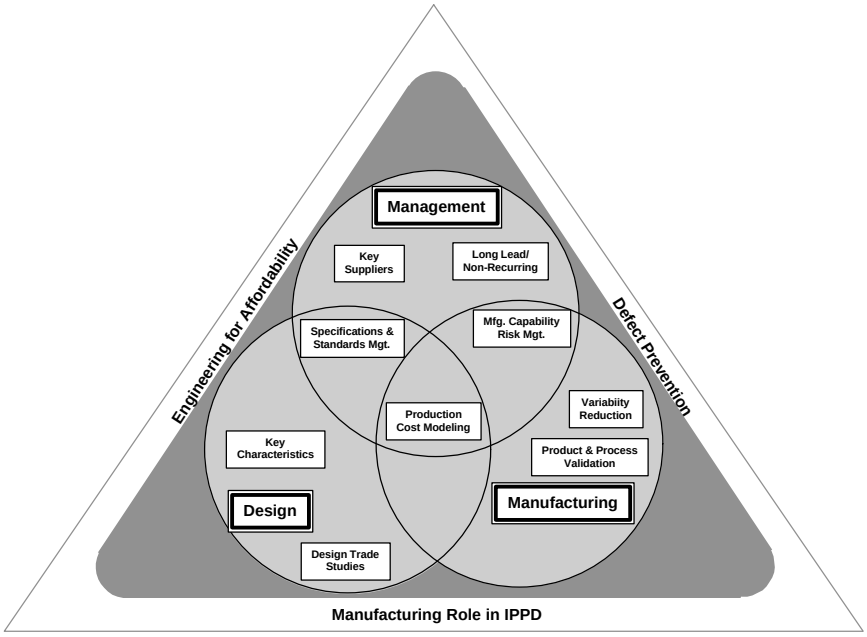


Figure 8-1 Functional Mapping of EMD Practices

In each of these subsections guidance is provided on Statement of Work (SOW) content, suggested IMP exit criteria, and PIO and evaluation criteria (Sections L and M). In all cases the suggestions should be evaluated and applied as appropriate for a specific program.

8.1.1 Suggested EMD Statement Of Objectives (SOO) Content

Manufacturing Development. The government's objective is that the contractor implement those processes and systems that considers manufacturing, quality, and design functions in achieving a balanced product design description which meet cost, schedule, and performance requirements with acceptable risk. Appropriate practices for implementation may include identification of key characteristics and processes; variability reduction on product, process, and infrastructure; electronic simulations of the manufacturing environment; cost modeling and Cost As an Independent Variable (CAIV); cost/performance trade studies; use of commercial parts and specifications; use of IPTs; and key supplier relationships.

8.2 Production Cost Modeling

8.2.1 Introduction

The intent of this practice is to provide a Production Cost Model (PCM) which can be used to estimate the projected production cost of the proposed design against a threshold value for affordability. The PCM must address all design driven cost elements and be maintained and

updated to stay current with the evolving product design and production plans. This model will have two major attributes: (1) the ability to be used as a design trade tool to assess the cost impacts of specific design changes and alternative production processes or process improvements; and (2) the ability to assess and accumulate design-related costs (as implemented in the factory) in a statistical manner which defines most probable costs.

The core elements of this practice will be found in the sections on the System Specification, the Integrated Master Plan (IMP) milestone exit criteria, and the Proposal Instructions to Offerors (PIO). The tasks associated with Production Cost Modeling will be closely related to the tasks for the design trade study activities discussed in Chapter 8, Section 8.3, Design Trade Studies, and other systems engineering tasks. The proposed IMP milestone exit criteria will also be linked closely to the overall systems engineering effort.

Figure 8-2 shows how this practice area integrates with other practices in the MDG framework.

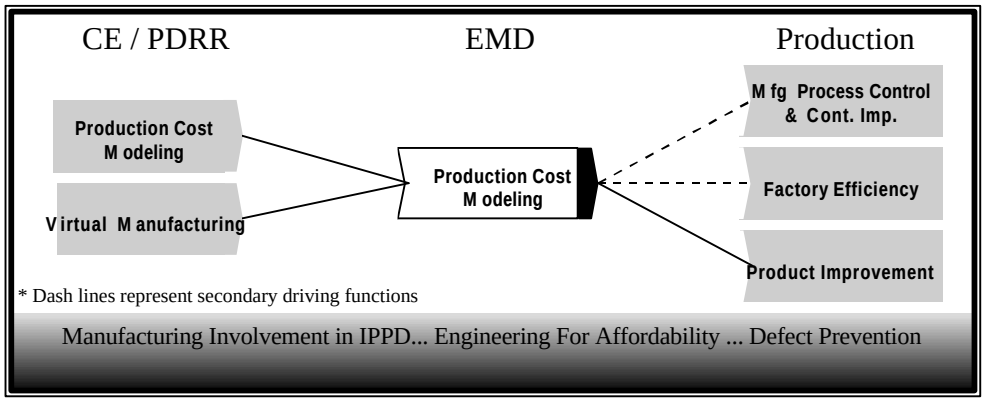


Figure 8-2. How Production Cost Modeling Integrates with Other Practices

8.2.2 Rationale

The need for a PCM during Engineering and Manufacturing Development (EMD) is driven not only by the increasing importance of affordability in weapon system acquisitions, but also by the need to improve Department of Defense (DoD) and defense industry performance in predicting and meeting cost and schedule requirements. Cost as an Independent Variable (CAIV) and other acquisition reform initiatives are techniques the government is using to reach this objective. The ability to balance cost, performance and schedule is an integral part of the Integrated Product and Process Development (IPPD) concept (see Chapter 3, Acquisition Strategy), but in order to balance cost, a cost requirement must be defined and must play an equal role in the systems engineering trade process. The establishment of a Production Cost Requirement (PCR) in the System Specification facilitates implementation of this effort. Production Cost Modeling enables evaluation of the product design cost estimates against the PCR in the System Specification, and permits realistic and timely cost/performance trade studies.

8.2.3 Guidance

The intent of Production Cost Modeling is to provide a tool for predicting and controlling design driven production cost. This includes the facilities and equipment required to implement the selected production processes. It is not intended that this activity attempt to control or predict indirect costs not controlled by the design (such as impacts of the overall business base). The specific cost components of the model must be sufficiently documented to provide an audit trail for subsequent adjustments and for verification.

For the contractor to develop a valid cost model, the government must define specific parameters to be used as assumptions in the model. These include variables such as constant versus then year dollars, production volume and rates, and any fiscal year budget constraints. The production volume and rates are important in defining the return on investment for capital equipment costs and other potential manufacturing investments which have a strong influence on product design. To avoid a "point" design solution, the production rates may be defined as ranges with the target rate identified, and overall production volume may be similarly defined. With few exceptions, the rate, volume, and other assumptions will have a significant impact on the final design and production cost. The assumptions should therefore be as realistic as possible and the rate/volume ranges as narrow as possible. Many commercial cost models are available for use and/or adaptation to fit company-unique accounting systems . The level of detail and the complexity of the cost models appropriate for a product will vary depending on the product's complexity, program size, and other factors.

Life Cycle Cost (LCC) defines true system affordability, as seen in Figure 8-3, but is difficult to predict with confidence during EMD. Therefore, a PCR is recommended as a more verifiable cost element. When combined with development cost, the PCR provides the baseline cost against which design trades can be accomplished in the implementation of CAIV. Support cost is obviously no less important, but there are a number of other product performance requirements (such as reliability, maintainability, and availability) which can be used as metrics for assessing progress in controlling support cost. The cost element to be controlled should be selected to satisfy specific program requirements, and may be, for example, Flyaway, Weapon System, Procurement, or Program Acquisition cost.

In most cases, it will be important to account for Special Tooling (ST), Special Test Equipment (STE), and Support Equipment (SE). Warranty costs should also be considered. The actual selection of the cost definition must be made on an individual program basis to control those costs considered most important. Cost requirements should consider both Government Furnished Property (GFP) and Contractor Furnished Property (CFP). It is also appropriate to include sustaining engineering and rate tooling in the requirement if these are likely to be cost drivers. It is essential that the program assumptions and basic definitions used in establishing the PCR be made available to the contractor for inclusion in the PCM. Any changes to those assumptions must be flowed down to the contractor for inclusion in updates to the PCM.

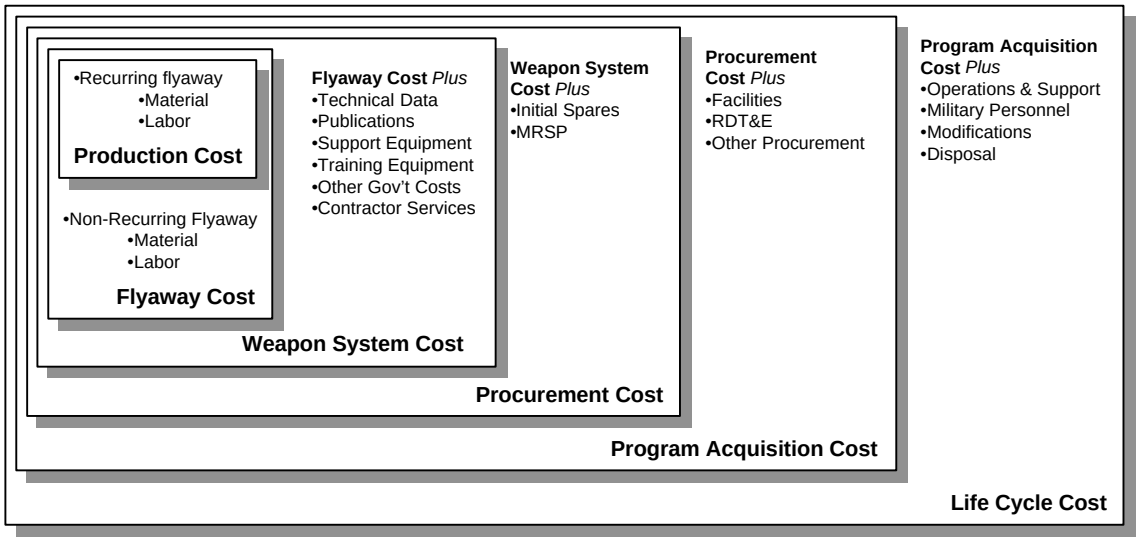


Figure 8-3. Life Cycle Cost

Cost analyses will be based on the most current hardware and software configuration using the validated procedures and assumptions established for PCM. Current production cost estimates should be available to support Technical Interchange Meetings (TIMs), Program Management Reviews (PMRs), and formal design reviews and technical audits. The contractor's PCM may be validated during source selection or after contract award. The primary use of the PCM in the EMD phase is to verify that the most probable cost of the applicable cost elements is equal to or less than the cost requirement stated in the System Specification. Recognizing that the intent is to define most probable cost, and that the ability to model production cost accurately at the start of EMD is virtually impossible, there will always be an uncertainty interval associated with the resultant estimate. This uncertainty interval will be relatively large early in the EMD phase, but should continuously shrink as the design and process capabilities solidify. Properly utilized, the PCM should play a significant role in the overall risk management effort.

The PCM will be developed using procedures and assumptions that have been agreed to by the Government and the contractor, and the agreement on these procedures and assumptions will represent the "validation" of the cost model. Any appropriate analysis procedure may be used in developing the PCM (parametric, historical, analogy, or detailed engineering estimates) depending on data availability and the maturity of candidate designs. The completed cost model must contain the appropriate data and relationships and must be maintained and updated to reflect program status changes. The PCM should include factors which account for inspection, test, scrap, and rework if applicable. Once validated and determined to be a reasonably accurate predictor of production cost and the relative cost impact of design changes, the PCM will be used for the final verification of design compliance with the System Specification cost requirement. When government data is needed for this analysis, the contractor will acquire it through the government contracting activity.

Cost elements included in the PCM must be clearly identified to preclude any misunderstanding, and must accurately reflect those assumptions and definitions used in establishing the PCR in the System Specification.

8.2.4 Lessons Learned

Past experiences with acquisition cost management have been generally unsatisfactory. Typically, Design To Cost (DTC) goals, rather than requirements, have been used, and the effort has usually tended to be a bookkeeping exercise in which, at best, an estimate of production cost was tracked and compared to the "goal." In many cases, the ground rules and assumptions became invalid through numerous program changes (such as changes in production volume or rate, or schedule slips), but little effort was made to maintain a truly valid estimate. This led to significant surprises in a number of programs when initial production contracts were negotiated.

8.2.5 Recommended RFP/Proposal Content

8.2.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 “Suggested EMD Statement of Objectives (SOO) Content.”

8.2.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs to the extent that they are applicable to the offeror’s proposed program:

- Development and maintenance of a PCM containing production cost ground rules, assumptions and data required to estimate production cost as defined in the System Specification.

- Incorporation of changes to the model and availability of change documentation to the government for review upon request.

- Implementation of the PCM as an element in the systems engineering trade study process to assess production cost impacts, and maintenance of an analysis of the current production cost estimate.

- Validation of the PCM (perform validation testing to prove that the PCM is a reasonably accurate predictor of production cost, including cost impacts due to design changes) in conjunction with the government. (Note: While it might be impractical to fully validate the model prior to EMD contract award, it should be validated as early in the post-award environment as practical. Updates to the assumptions and the calculational basis of the model will require government approval.)

- Use of the production cost estimate analysis to assess the risk of achieving the System Specification cost requirement, and formulation and execution of appropriate risk abatement efforts.

8.2.5.3 Integrated Master Plan (IMP) Exit Criteria

The PCM will play a key role in assessing the overall progress of the development program, and the current cost estimate and trends at the IMP milestones will weigh heavily in the decision to proceed to the next phase.

Interim Event (corresponding to historical Preliminary Design Review):

- Contractor PCM validated and under formal configuration control.
- CI cost allocation complete and rationale provided for allocation.
- Rationale provided to correlate initial cost estimates and cost risk mitigation effort to achieve an acceptable production cost estimate.

Interim Event (corresponding to historical Critical Design Review):

- Rationale provided to correlate cost estimates based on detailed design and cost risk abatement effort to achieve an acceptable production cost estimate.

Interim Event (corresponding to historical System Verification Review):

- Rationale provided to correlate final cost estimate based on development test results, test article build experience, (and, when applicable, Low Rate Initial Production [LRIP]) and any remaining cost risk abatement effort to be completed prior to production which results in an estimate which meets the System Specification PCR.

8.2.5.4 Contract Data Requirements List (CDRL) Guidance

- Initial PCM cost estimates submittal within ___ days after contract award for government validation.
- Final PCM cost estimates submittal with formal cost verification assessment ___ days prior to Milestone III.

8.2.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Established processes and procedures for developing and validating a PCM.
- Documentation and maintenance practices for control of the PCM configuration.
- The contractor's preliminary model for evaluation, if available.

- Data pertinent to prime contractor and key supplier past performance in developing and maintaining realistic PCMs or similar models.

8.2.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Production Cost Modeling should be based upon:

- Robustness of the contractor's processes and procedures for developing and validating a PCM.

- Maturity of the documentation and maintenance practices for configuration control of the PCM.

- Status of the contractor's preliminary model, if available.

Past performance in developing realistic production cost models for similar systems.

8.3 Design Trade Studies

8.3.1 Introduction

The role of design trade studies in the manufacturing development process is to achieve a product design that effectively balances the system design with respect to the cost, schedule and performance. The systems engineering trade study process employed by the contractor should represent the methods by which cost and performance trades are performed (using a validated production cost model). The benefits of utilizing commercial parts and processes and the affordability penalties resulting from the use of non-standard parts and processes should also be accounted for in documentation of design trade-off decisions.

Figure 8-4 shows how this practice area integrates with other practices in the MDG framework.

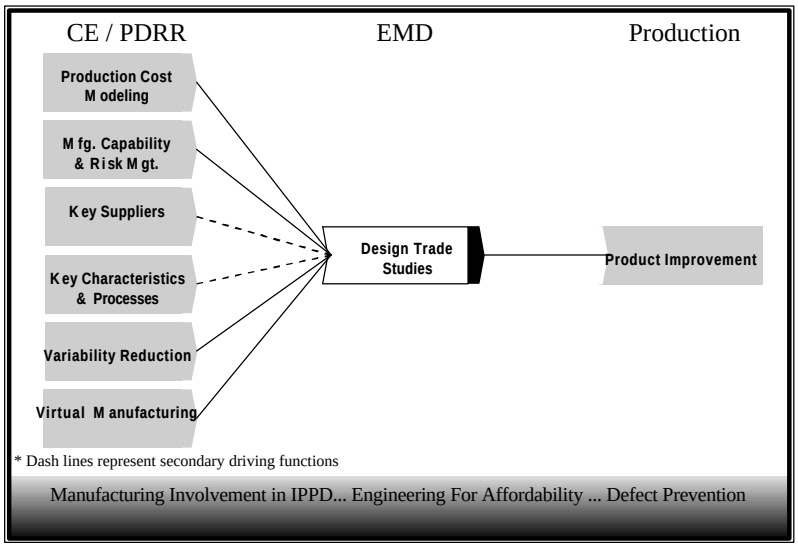


Figure 8-4. How the Design Trade Studies Practice Area Integrates with Other Practices

8.3.2 Rationale

Institutionalizing the full consideration of producibility and supportability as part of the systems engineering design trade study process is essential to the overall goal of affordable weapon system acquisition. The development of a reliable production cost model (Chapters 6 and 7, Sections 6.1 and 7.1, "Production Cost Modeling"), and the participation of manufacturing engineering in the design Integrated Product Team (IPT) allow the system cost metric defined as the Production Cost Requirement (normally either the AUPP or DTUPC) to be used as a design trade parameter in meeting the system performance and cost requirements. Acquisition reform has greatly expanded the options available to design and manufacturing engineers. The freedom to use commercial or contractor-defined and controlled processes gives the contractor the flexibility to propose a system design that takes maximum advantage of the development team's unique capabilities. The potential for trading cost verses performance makes available the significant benefits of Commercial off the Shelf (COTS) products to the design team.

Another key element of the design trade study practice is the participation of both the government customer and key suppliers in the product IPTs and in the trade study process. The intent is to ensure a fully integrated design effort which meets the customer's needs while considering producibility and supportability to minimize life cycle cost. Improved communications between the engineering and manufacturing personnel and between prime contractor and suppliers helps to avoid integration problems which could compromise system performance or require redesign of one or more components.

8.3.3 Guidance

The careful consideration of producibility and supportability is a key element of the Integrated Product and Process Development (IPPD) concept. To be truly effective, the design trade study

process should identify alternative production processes and consider the economic loss functions, as described in Chapter 8, Section 8.7, Key Characteristics and Processes, for each potential alternative. Other tools, such as Design of Experiments (DOE) or Quality Function Deployment (QFD) methods, are also available for evaluating the viability of design alternatives. The design trades should strive for robust product designs which are tolerant to variation in the intended manufacturing, assembly, test, and usage environments. They should be capable of selecting the design which represents minimum life cycle cost within the program constraints. With key suppliers acting as full members of the design team, both the functional allocation and the resultant integration of all components into the system are enhanced.

The trade studies should include consideration of the product, production processes, Special Tooling, Special Test Equipment, and Support Equipment (ST/STE/SE). The absolute performance requirements ("must haves") provided in the System Specification form the baseline. However, design margins should be identified for each of the items in the System Specification. The contractor should have the flexibility to address how much margin is applied within program cost and schedule constraints. Additional capabilities above the requirements may be found within these constraints, and the contractor should be encouraged to identify opportunities for improved capabilities. Two areas that should be addressed in the Design Trade Study process are the impacts on system performance and cost (both production and life cycle cost) of the use of COTS and non-standard parts and processes. The affordability aspect of COTS and non-standard parts and processes must, in particular, be evaluated with respect to life cycle cost considerations such as maintainability and reliability.

This practice deals primarily with the effort leading to the design of the product and ST/STE/SE. There are six central elements to this effort:

1. Flowdown of the design trade study task requirements to the suppliers, and participation of key suppliers in the design IPTs.

2. Integration of the trade study efforts into the Integrated Master Plan (IMP) with identification of the contractor's key events supporting the IMP milestones.

3. Completion and documentation of the trade studies which result in the product and ST/STE/SE designs.

4. Presentation of the status of the trade studies and rationale for utilization of the trade study results at key events and IMP Milestones.

5. Performance of risk assessments and implementation of risk abatement efforts.

6. Identification of opportunities for additional product / process improvement which may exceed existing program constraints of cost and/or schedule, but which could provide significant long-term benefits to system cost, schedule, and/or performance.

8.3.4 Lessons Learned

Two areas related to design trade studies have been the source of difficulties in the past: design for production, and effective communication with respect to requirements between primes and suppliers. Past practices have relied on a serial development effort between product and process. During pre-Production, virtually all of the development emphasis was placed on system performance. Once the required performance was functionally demonstrated, an attempt was made to transition the design to production. The manufacturing engineering function then tried to adapt existing processes to manufacture the "qualified" design. The result was a sub-optimal design from two respects: (1) little or no attempt was made to optimize the product design for existing process capabilities; and (2) new or improved processes received little consideration. Considering producibility and supportability throughout the design process promises a smoother transition to production. Reaching rate production capabilities should also be easier and more efficient as processes are continuously improved.

In the past, the functional allocation and initial designs for the weapon systems have often been completed with little or no participation by key suppliers. The prime contractor/supplier relationship has been primarily controlled by product requirements defined in specifications, drawings, and interface control documents. Since the suppliers frequently had little understanding of how the product was actually to be used, their design would often meet all performance requirements, yet not integrate easily or completely into the weapon system. The result would be a series of redesigns or compromises in overall design quality. By integrating the key suppliers into the prime contractor's design team, the ability to transmit actual requirements and to make trades for producibility and supportability at the subsystem and component levels should be greatly enhanced. Pertinent experience at all levels accrued by contractor personnel who have participated in interface control working groups will be useful as they adapt to the operating philosophy of joint IPTs.

8.3.5 Recommended RFP / Proposal Content

8.3.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 "Suggested EMD Statement of Objectives (SOO) Content."

8.3.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

A design trade study process that establishes the detailed designs of the overall weapon system and ST/STE/SE, to include selection of fabrication and assembly techniques and design parameters and tolerances that are consistent with process capabilities..

- Identification of key product characteristics and related key production processes.

- Identification of alternative materials and production processes and assessment of overall production costs, including the economic loss function describing the costs associated with producing off-nominal product characteristics.

- Performance of critical path analyses of the IPT tasks and the process for reporting progress against the critical path.

- Flowdown of appropriate design trade study task requirements to key suppliers.

- Documentation of design trade study results and disposition of resultant recommendations as the design matures.

- Rationale for the functional requirements allocations and the resultant detailed designs at appropriate key events and IMP Milestones.

- Identification of design trades which fall outside program constraints of cost or schedule, but offer the potential of significant cost, schedule or performance improvements.

8.3.5.3 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

- Functional allocation of System Specification requirements, including the Production Cost Requirement and overall estimate of Life Cycle Cost.

- Design trade process implemented for evaluating alternative materials and production processes and identifying key product characteristics and related key production processes, including the results of key supplier efforts.

- Contractor's planned key events and their exit criteria, as reflected in the IMP.

Interim Event (corresponding to historical Critical Design Review):

- Detailed design (product/ST/STE/SE) including production cost assessments and key product characteristic's design limit sensitivity to off nominal production; details to include the results of key suppliers' efforts.

- Selection of production processes, including comparison of required process capabilities to documented capabilities.

- Contractor’s planned key events and their exit criteria included in IMP.

Interim Event (corresponding to historical System Verification Review):

- Final product/ST/STE/SE design based on results of test and evaluation, including the results of key suppliers' efforts

- Identification of potential opportunities for improving cost, schedule and/or performance beyond baseline requirements.

- Contractor's planned key events and their exit criteria included in IMP.

8.3.5.4 Contract Data Requirements List (CDRL) Guidance

For on-going single source production programs:

- Information copies of specifications and product descriptions through the Data Accession List (DAL), with delivery upon request.

For multiple source production or delayed production programs:

Option 1: Contractor maintained library

- Information copies of specifications through the DAL, with delivery upon request.

Option 2: Government maintained library

- Product Development Definitions upon completion.

- Product Design Definitions upon completion.

- Product Fabrication Definitions at Milestone III.

- Technical Data Package and Build-to Package at Milestone III.

8.3.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Basic trade study processes to be employed, including selection criteria for principal participants and integration of planned design trade studies and results into the IMP.

- Process for System Specification requirements allocation and flow down.

- Implementation of requirements for ST/STE/SE during the design process.

- Data pertinent to the prime contractor's and key suppliers' past performance in accomplishing design trade studies, with emphasis on such studies performed under the IPT concept, including metrics which identify performance with respect to cost, schedule and product performance.

8.3.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Design Trade Studies should be based upon:

- Established processes for performing and documenting design trade studies and the planned integration of design trade studies and results into the IMP.
- Established process for System Specification requirements allocation and flow down.
- Established processes for addressing the ST/STE/SE requirements as part of the design trade study process
- Past performance of prime contractor and key suppliers in accomplishing design trade studies, with emphasis on such studies performed under the IPT concept.

8.4 Specifications and Standards Management

8.4.1 Introduction

Specifications and Standards Management addresses the goals of (1) maximizing the use of commercial standards and specifications when they meet military requirements; (2) tailoring out unnecessary requirements; and (3) underscoring the government's move to a Performance Based Business Environment (PBBE). In the increasingly competitive worldwide market for commercial products, many contractors have implemented standards and specifications for material, workmanship, and production processes which meet or even exceed military requirements. It is the intent of this initiative to take advantage of benefits provided by the use of these strengthened commercial standards and specifications.

The primary effort associated with this subject is contained in the Proposal Instructions to Offerors (PIO) guidance and the evaluation criteria guidance. This effort involves establishing a contractor's ability to: (1) responsibly develop and maintain a complete set of standards, specifications, and processes that meet program requirements; (2) Establish and maintain complete Build-to and Support-to packages; and (3) provide supporting rationale for the final selections. Specific Integrated Master Plan (IMP) exit criteria are also defined, and formal data items may be required in the Contract Data Requirements List (CDRL). The use of commercial specification and parts is closely linked with the design trade study process described in Chapter 8, Section 8.3, Design Trade Studies.

Figure 8-5 shows how this practice area integrates with other practices in the MDG framework.

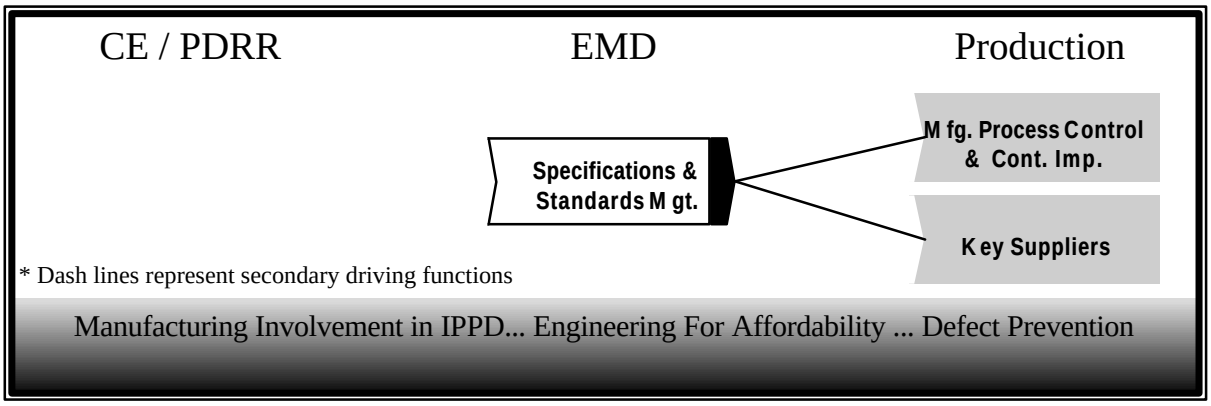


Figure 8-5. How the Specifications and Standards Management Practice Area Integrates with Other Practices

8.4.2 Rationale

A Performance Based Business Environment, in accordance with Department of Defense (DoD) policy, allows limited usage of Military Specifications and Standards. For new acquisitions, the only military specifications and standards permitted by the government procuring authority will be those for performance specifications, select product specifications (such as those for jet aircraft fuels, MIL-T-5624R), and interface specifications (such as those for military armament, MIL-STD-1760). Contractors thus have increased responsibility and control over the design throughout Pre-Engineering and Manufacturing Development (Pre-EMD), EMD, and Production and will be responsible for generating and controlling the technical data package at each level of the specification tree. The contractor's objectives in this environment should be: (1) to describe the design in sufficient detail that any item may be replaced without requirements for external adjustment to achieve interchangeability or interoperability; and (2) to exploit the affordability advantages available with the use of Commercial off the Shelf (COTS) items, commercial practices and processes, and Single Process Initiatives (SPIs).

8.4.3 Guidance

The implementation of acquisition reform initiatives associated with performance based business environments has led to the disestablishment of most government standards for materials and processes. This change will drastically alter the way industry and the government relate and conduct business. In order to function effectively under the new acquisition philosophy, it is imperative that some basic principles of a PBBE be recognized and understood:

- Performance requirements for the products to be procured are necessary at all levels from top system level requirements down to the lowest reparable level.

- Flowdown of the technical and cost requirements to the lowest level of the supplier chain is essential and must be accomplished if the benefits of acquisition reform are to be realized.

- Performance based specifications must become the standard means of communication between all levels, from government to prime contractor to supplier.

- The support package should be derived from the build-to package, so that the two packages have a common technical basis.

- The essential performance attributes that were contained in previously used Military Specifications and Standards must now be incorporated in the appropriate product specifications.

- Determination of who controls the technical data packages at each level of the specification tree will be driven by: program and technical risk, contractor capabilities, and business strategies. Contractors exhibiting the capability for self-governance will be given greater authority and responsibility than those who do not.

Figure 8-6 illustrates the basic design and verification process flow, and some of the basic supporting elements of the technical data package, such as the Interface Control Documents (ICDs) and the Product Acceptance Criteria (PAC).

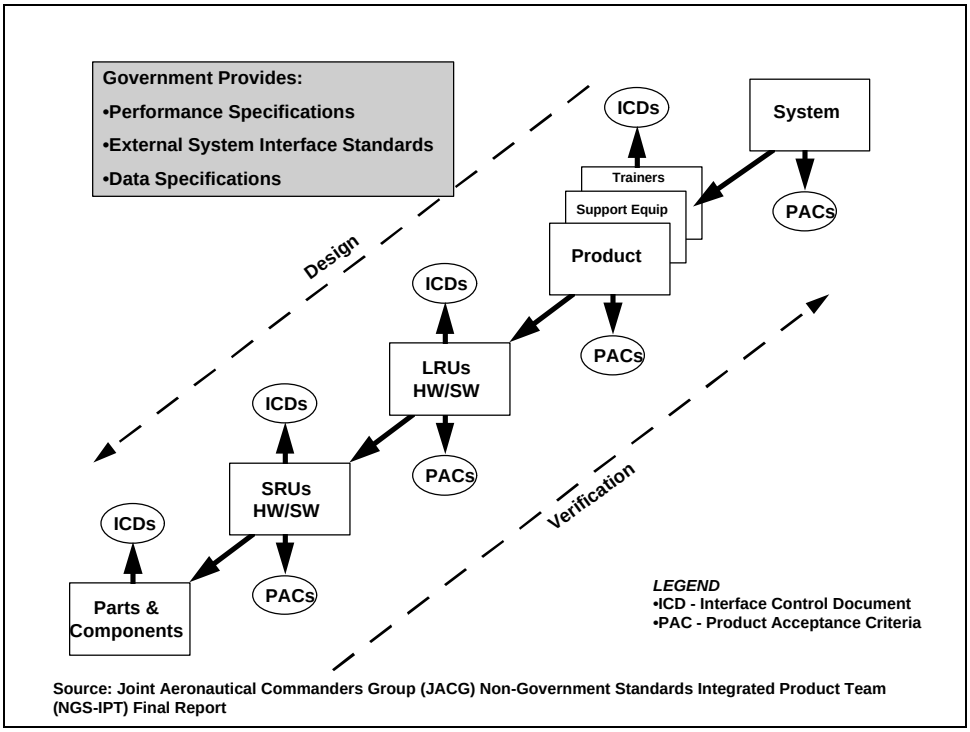


Figure 8-6. Design and Verification Flow Process

PBBE requires a disciplined systems engineering process throughout design, design verification, fabrication, process verification, and product acceptance. This results in an allocation with complete definition from the system level down to the lowest reparable item level. The two-part description historically used for defense acquisitions may not provide the efficiency or level of detail required. A three-part description system is recommended for utilization below the

system level to ensure that the requirements, product definition, and process definition are complete. The three-part part description which comprises the technical data package consists of the following:

Part 1 -- Development Definition

Part 2 -- Product Design Definition

Part 3 -- Product Fabrication Definition.

A complete, detailed discussion of the three-part product description is included in the Joint Aeronautical Commanders Group (JACG) Non-Government Standards Integrated Product Team (NGS-IPT) Final Report[1]. The acquisition model shown in Figure 8-7 illustrates the framework for producing a technical data package in the performance based business environment, with the government/prime contractor and prime contractor/supplier relationships shown. The government provides system performance requirements in the form of a System Requirements Document (SRD). The prime contractor prepares and proposes performance based development definitions (Part 1) which are used as the basis of the contract.

[1] Joint Aeronautical Commanders Group (JACG) Non-Government Standards Integrated Product Team (NGS-IPT) Final Report, 29 February 1996. Digital copies of this report in Adobe *Portable Document Format* (.pdf) can be obtained at: http://www.wpafb.af.mil/ngs/. Adobe Acrobat Reader can be obtained at: http://w1000.mv.us.adobe.com/Acrobat/readstep.html.

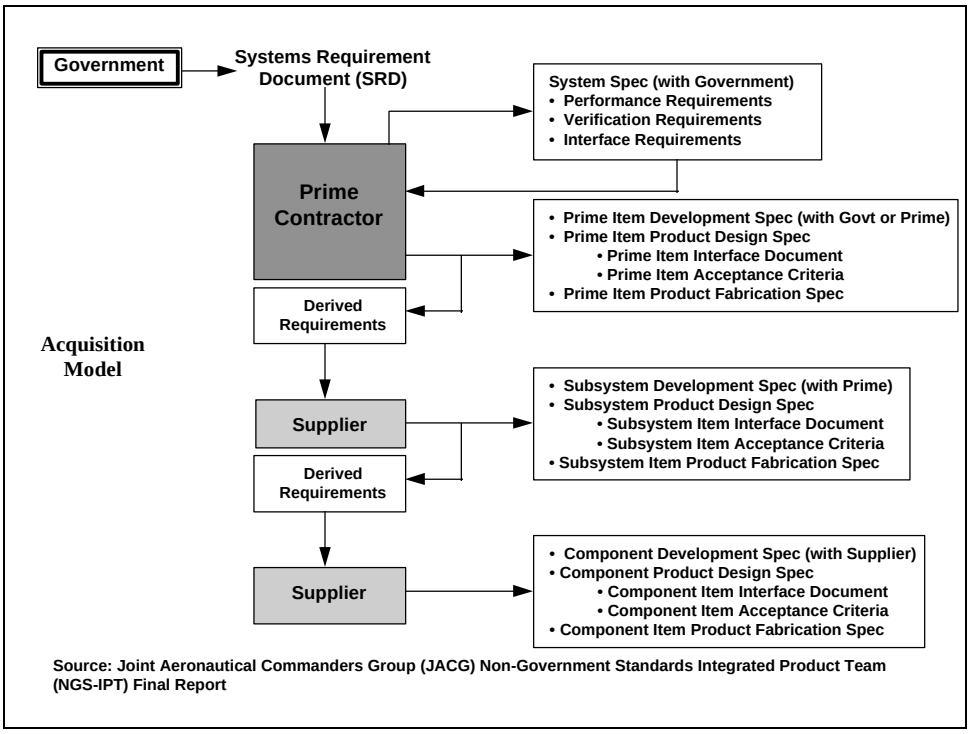


Figure 8-7. Acquisition Model

The contractor allocates requirements for the entire system design through a systems engineering process (see Chapter 4, Manufacturing Engineering's Role in IPPD, and Chapter 5, Engineering for Affordability) and provides these allocated performance requirements to other suppliers. (In this context suppliers can be subcontractors, vendors, or an organic component of the prime contractor's organization; as dictated by the prime contractor's business strategy). The Part 1 development definitions are used as the basis for contracting at each lower supplier level. The contractor or supplier translates the development definition requirements into the Part 2 product design and Part 3 product fabrication definitions as appropriate. (Note that logistics performance requirements such as reliability and fault detection and isolation, are included in this process). It is critical that the specifications and product definitions be maintained and kept current as the design evolves.

The technical data package must capture and detail the key product characteristics that have been derived from the allocated requirements defined in the Part 1 definition, as well as the product acceptance criteria and the complete interface requirements of the Part 2 definition. While specific, the Part 1 and Part 2 definitions are still written in performance based terms. The result is flexibility in the technology choices used in the design of the product, flexibility in the fabrication processes utilized to produce it, and flexibility in the selection of tools for accepting the product. A complete technical data package is still necessary to ensure interchangeability and interoperability and to allow for the use and incorporation of commercial open systems and commercial technology when appropriate. Additionally, it would form the basis for the design, verification, production, and support of safety-critical parts and components. It would also delineate the special requirements which must be satisfied for this class of parts.

One of the essential aspects of preparing a complete technical data package is an established and documented drawing system that applies the techniques of geometric dimensioning and tolerancing. Proper use of geometric dimensioning and tolerancing will minimize the occurrence of assembly interferences and support problems. These drawing techniques may be implemented by tailoring American National Standards Institute (ANSI) Document Y14.5M, Dimensioning and Tolerancing. The applicable sections of ANSI Y14.5M include sections 1.4, Fundamental Rules, and 4, Datum Referencing. The contractor's drawing standards may fulfill this requirement if they meet the intent of the ANSI document. An essential element of datum control is the incorporation of the datum in the tooling design. In the Integrated Product and Process Development (IPPD) environment the development of Special Tooling (ST) will be accomplished in parallel with product development.

8.4.4 Lessons Learned

Historically military standards have been used to direct the processes used by contractors. Some have dictated organizational structures, prescribed detailed tasking and task flows, and been contractually binding. The ability to achieve affordability is directly influenced by how well we can define the minimum set of requirements for both products and processes. To take full advantage of the expected cost avoidance made possible by PBBE and commercial parts and processes, it will be essential that the true requirements for the products and processes are fully understood by both the contractor and the government. The government representatives must work closely with the contractors, including key suppliers, to minimize the review effort. This will require qualified government specialists dedicated to accomplishing this task.

8.4.5 Recommended RFP / Proposal Content

8.4.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 "Suggested EMD Statement of Objectives (SOO) Content."

8.4.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Development and maintenance of a complete Technical Data Package.
- Formal document control of the lower level specifications and Technical Data Package.
- Development and maintenance of complete Build-to and Support-to packages derived from the Technical Data Package.
- Implementation of Commercial parts, practices, and processes.

8.4.5.3 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

- Prime Item Development Specification.

Interim Event (corresponding to historical Critical Design Review):

- Prime Item Product Design Specification.

Interim Event (corresponding to historical System Verification Review):

- Prime Item Product Fabrication Specification.

Milestone III Production or Fielding/Deployment Approval:

- Approved Technical Data Package.

8.4.5.4 Contract Data Requirements List (CDRL) Guidance

The primary product of this effort will be the product definition specifications. Delivery of the documentation which results from this effort will be by EDI and is highly dependent on program requirements, but should be delayed as long as practical. Information copies of specifications and product definitions should be available through the Data Accession List (DAL) as required and will be presented by the contractor for the Data Update Events (DUEs) as listed. In addition, increased use of contractor formatting is encouraged (except for in those cases where standard formats are required for use across multiple programs), in order to minimize the administrative burdens and costs. Adequate documentation must be maintained by the contractor to provide a clear documentation trail for audit and product/requirement compliance verification.

- (DUE) Information copies of product definitions, specifications, and draft Technical Data Package through the DAL.
- Prime Item Product Development Specification.
- Prime Item Product Design Specification.
- Prime Item Product Fabrication Specification.
- Approved Technical Data Package.

8.4.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the achievement of the goals of this practice will be ensured, including the following:

- The processes established for development, use, and maintenance of performance specifications, along with relevant past performance data
- Processes, documentation practices, and past performance for requirements flowdown and design configuration control.
- Evidence of the use of performance based specifications in dealing with suppliers.
- Drawing and documentation standards employed.
- Evidence of the use of commercial parts, practices, and processes; and any pertinent experience with Single Process Initiatives.

8.4.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Specifications and Standards Management should be based upon:

- Past performance in the development, use, and maintenance of performance specifications.
- Past performance in requirements flowdown and configuration documentation and control.
- Processes established for requirement and performance specification flowdown to suppliers, along with relevant past performance data.
- Drawing and documentation standards employed.
- Past experience with and planned implementation of commercial parts, practices, and processes, and Single Process Initiatives.

8.5 Manufacturing Capability Assessment and Risk Management

8.5.1 Introduction

The manufacturing capability assessment and risk management effort is a structured, disciplined approach to evaluating available and forthcoming manufacturing capabilities in order to identify, assess, and manage risk. It applies formal risk mitigation processes from the very inception of the program in order to provide a continuous assessment of program progress against clearly established baseline requirements. A key focus of the manufacturing capability assessment and risk management effort is to anticipate and eliminate the schedule delays, technical compromises, and cost overruns which have historically been associated with the critical period of transition from design to production in major programs. (For other key aspects of risk management, see Sections 8.2 and 8.3, Production Cost Modeling and Design Trade Studies.)

In the new Integrated Product and Process Development (IPPD) acquisition environment, Low Rate Initial Production (LRIP) is moved forward from the production phase to the EMD phase of the program. This is done to ensure an early focus on eliminating manufacturing problems before they impact production costs more significantly, as would be the case at higher production rates. The production readiness of the LRIP hardware can now be established ahead of time through incremental verification and validation of processes and process capabilities, production planning, simulation of the manufacturing process, maximizing the use of production processes for test articles, and other efforts and assessments.

New approaches such as virtual manufacturing, virtual prototyping, and virtual assembly (see Chapter 7, Section 7.7) minimize transition difficulties. Rate build up capability can be assessed using these same approaches. The contractor is responsible for the maturity of his production capabilities. If additional development of production capabilities is required as the design evolves, the contractor should rely on incremental verification steps to validate that the required maturity has been achieved.

It is absolutely essential that manufacturing risk be fully integrated into the program's overall risk management effort. (See Chapter 7, Section 7.3 on Manufacturing Capability Assessment and Risk Management in the Concept Evaluation and PDRR phase.) In the RFP, therefore, manufacturing capability assessment and risk management issues should be integrated with the program management risk and systems engineering sections, since tasking areas such as the design trade studies, production cost modeling, and the requirements verification efforts will be key elements of the risk management process.

Figure 8-8 shows how this practice area integrates with other practices in the MDG framework.

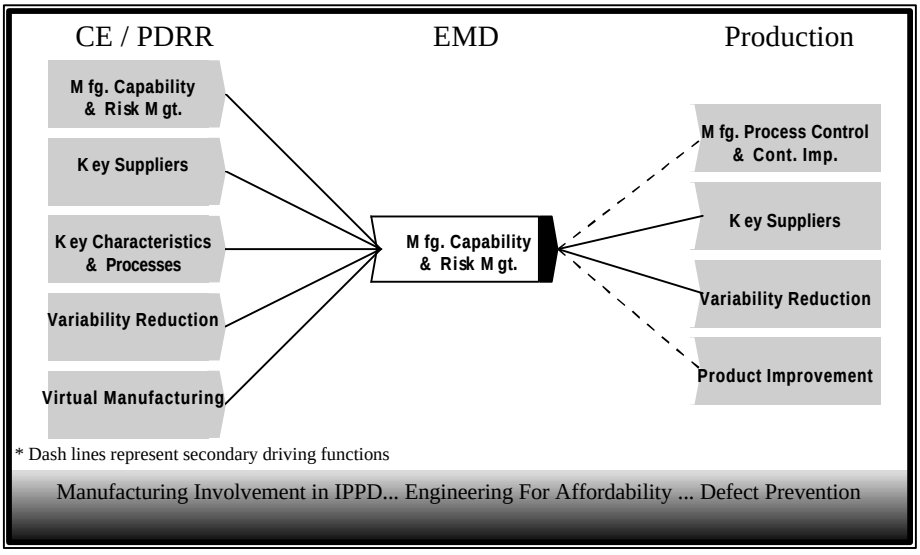


Figure 8-8. How the Manufacturing Capability Assessment and Risk Management Practice Area Integrates with Other Practices

8.5.2 Rationale

A manufacturing capability assessment and risk management effort that starts early and is maintained throughout the development process is a key part of the IPPD approach to weapon system acquisition. The concept of concurrent product and process development lowers both transition risk and overall program risk by applying to the development and qualification of the production processes the same disciplined systems engineering approach used for product development.

The strengthened emphasis on concurrent process development and verification, along with the parallel design and development of Special Tooling/Special Test Equipment/Support Equipment (ST/STE/SE), introduces a significant level of new effort that must be managed in the early stages of EMD. It is therefore vital to implement an approach to risk identification which facilitates program decision-making, evolves the appropriate risk mitigation measures, and includes them in the program's Integrated Master Plan (IMP).

In addition to the careful identification and management of the risks associated with product and process development, it is essential that thorough planning for production occur early in EMD. Virtual manufacturing tools, maximizing the use of production processes during the build of test articles, and the use of line proofing are measures which provide verifications of producibility. The objective is to fully support Low Rate Initial Production (LRIP) at the end of EMD, and to prepare for full rate production. All resources (including manpower, facilities, plant equipment, ST, STE, and SE) must be in place for LRIP.

Almost any aspect of a development program can be a source of manufacturing risk. The selection of materials or design directions which require new kinds of production processes is one example. Processes which lack the capabilities to meet quality requirements are another. With the heightened emphasis on team performance, the integration of supplier risk into the total risk management effort is essential. This includes both subcontractors and Government Furnished Property (GFP) suppliers. (While the contractor will not be responsible for the conduct of GFP supplier risk management efforts, it will be necessary to factor any risk associated with GFP into the weapon system program and adjust the IMP.)

8.5.3 Guidance

The structure of the overall program risk management effort may differ from one program to another, but the essential elements will be the same. The identification and assessment of risk will be a function of the systems engineering process, with participation by all affected functions. During the design phase, this will be a significant factor in the design trade studies. During the test and verification phases, the design trade studies form the basis for assessing and resolving problems which arise both product and process areas.

Production planning was previously the focus of a series of incremental Production Readiness Reviews (PRRs), typically begun in the Preliminary Design Review (PDR) time frame and finalized late in EMD, in time to support the Milestone III production go-ahead decision. The MDG replaces the PRR with a more comprehensive manufacturing review function which begins

at the start of EMD and continuously assesses and manages risk at both the prime contractor and supplier level. Manufacturing risk reviews and reporting should be a formal part of the Technical Interchange Meetings (TIMs) or equivalent system and subsystem reviews. The contractor assesses the completeness of the production process verification as part of the formal IPT process. The Program Office may tailor a Manufacturing Risk/Readiness Review (MR/RR) for the program if risk identification warrants it. With the increased use of commercial-off-the-shelf (COTS) equipment projected for acquisition programs in the new environment, industrial base capacity can easily become a risk factor which needs to be assessed and mitigated.

Another contribution of manufacturing personnel to the risk management effort is their input to the overall program Environmental Assessment (EA). The manufacturing processes for both production and support may be responsible for a significant part of the overall environmental impact of the program. The design trade studies should address this issue as part of the overall program cost. In particular, design producibility trade-offs should emphasize non-selection of hazardous materials and processes. Be sure to address not only materials that make up the end item product but also materials used in manufacturing processes that emit volatile organic compounds into the atmosphere (an area of EPA concern) or those that are hazardous to production work force safety (an area of OSHA concern). Accordingly, a separate and continuous process for monitoring and assessing environmental implications is a key requirement.

The development of risk mitigation plans and the inclusion of these plans in the IMP is a key part of the program management effort. Close coordination among those who develop the various sections of the RFP is essential to avoid duplication of effort while ensuring that the required activities are accomplished. Contractors should be given the flexibility to implement the risk management effort efficiently within their company structures while providing appropriate insight for and receiving adequate support from the government technical and management team.

8.5.4 Lessons Learned

Contractors on major programs who have achieved an efficient, on-schedule exit from EMD into LRIP are typically characterized by a disciplined approach to risk management of all areas of the program, including the supplier base. From the earliest CE and PDRR stages through EMD on these programs, the areas of risk have been addressed with formal risk mitigation efforts and systematic management attention to cost and schedule issues. Parts with high manufacturing risk are identified in Pre-EMD phases. During EMD, process development and validation programs are created for these parts. The identification of Key Characteristics and related Key Processes in the Pre-EMD phases enables the IPT to focus on those processes which create risk. The government has also recognized the importance of industrial base sustainment during the down sizing of industry and promoted judicious employment of these resources on new programs.

Prior to EMD numerous trade studies are generated that support early design decisions. Given the magnitude of engineering change activity geared toward making the initial design more robust during EMD, a key EMD challenge is the need to update those early trade studies by assessing the potential effect of proposed changes on producibility.

8.5.5 Recommended RFP/Proposal Content

8.5.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 "Suggested EMD Phase SOO Content."

8.5.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to address the topics below in their submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- How IPPD procedures will apply to process and production capabilities in EMD.
- Risk mitigation strategies for material and process issues.
- Concurrent development of ST/STE and SE as a schedule risk reduction procedure.
- Progress toward achieving a robust product design in order to reaffirm tooling philosophy.
- Capability or capacity issues, industrial base sustainment plans, and any foreign-sourced materials included.
- Metrics used for evaluation of producibility and other cost issues in the design trade studies, including those of key suppliers.

8.5.5.3 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

- Manufacturing Capability Assessment updated.
- Preliminary test article build plan complete.
- Rationale provided to demonstrate adequacy of risk abatement plans.
- Risk abatement milestones included in IMP.
- Process capability database includes all key processes.
- Plan identified to match product requirements and process capabilities.
- Supplier capacity risks identified and included in risk management planning.
- Plan for COTS/industrial base risk complete.
- Preliminary LRIP plan complete.

Interim Event (corresponding to historical Critical Design Review (CDR):

- Manufacturing Capability Assessment updated.
- Test article build plan complete.
- Rationale provided to demonstrate adequacy of risk abatement plans.
- Process capability demonstration plan complete and included in IMP.
- LRIP plan complete.

Interim Event (corresponding to historical System Verification Review (SVR) :

- Rationale provided to demonstrate adequacy of production risk mitigation plans.
- Process capability verification complete.

8.5.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

8.5.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

- The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following: The overall risk management process, including management of key supplier risks (both subcontractors and GFP suppliers)
- How the specific manufacturing risks will be addressed, including the metrics to be used and how risks will be documented and reported.
- How the risk management effort will be integrated with the overall systems engineering and IPD processes.
- Process capability database includes all key processes.
- Industrial base sustainment issues.
- Effective minimization of all hazardous materials.
- Inclusion of the environmental assessment task in the Integrated Master Plan.

8.5.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ risk management for the assessment of manufacturing capabilities should be based upon:

- Identified process capabilities of the prime and key suppliers, with linkage to process requirements.

- Inclusion of all shortfall items in the Risk Management Plan, the IMP, and/or the program schedule.

- Addressing of supplier capacity constraints and industrial base sustainment issues in the Risk Management Plan.

- Addressing environmental assessments and environmental impacts.

8.6 Key Suppliers

8.6.1 Introduction

Key supplier partnerships and strategic business alliances have become critical factors in defense system acquisitions. Partnerships foster joint commitments between companies and promote shared investments in product design and development. Resource sharing and mutually focused internal research and development activities result in more aggressive, more efficient problem solving and product development. It is not the intent of these guidelines to promote a business strategy of either exclusive partnerships or sustained competition, but to promote supplier participation in the program teaming structure and in development, proposal, and design activities as soon as business strategy decisions are made. This kind of early supplier participation will allow the entire team to exploit complementary strengths, address weaknesses, and take mutual ownership of problems and solutions.

A key supplier, including suppliers of Government Furnished Property (GFP), under the Manufacturing Development Guide (MDG) philosophy, is a supplier at any level whose performance in the areas of cost, schedule, or technical performance, is essential to the development and production of an effective, affordable system. There are several criteria that can result in a supplier being deemed "key," such as:

- If the requirements flowdown process, as shown in Figure 8-9, results in a supplier's "product characteristic" being essential to achieving the "system attribute (requirement)" then the supplier should be considered a "key supplier. "

- If a supplier is identified as "sole source" because of unique technologies or unique manufacturing capabilities, the supplier should be considered a "key supplier. "

- Excessive risk, either in cost, life cycle affordability, or technical performance, with no low-risk alternative available, could justify a supplier being considered a "key supplier. "

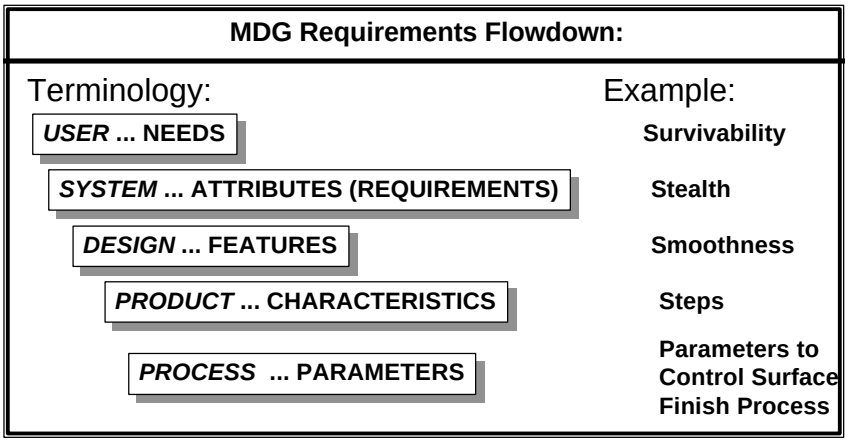


Figure 8-9. Requirements Flowdown

Figure 8-10 shows how this practice area integrates with other practices in the MDG framework.

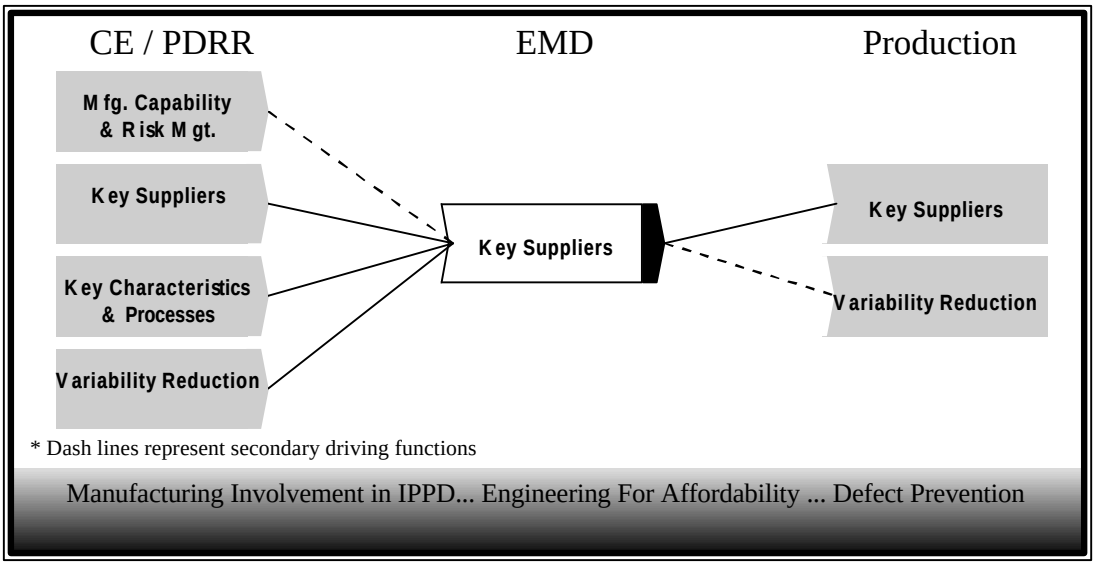


Figure 8-10. How the Key Suppliers Practice Area Integrates with Other Practices

8.6.2 Rationale

Supplier performance is increasingly important as the percentage of work performed at the subcontractor level on weapon systems programs continues to grow. Various studies have shown that once a program reaches production, supplier activities typically account for more than 60% of the total production cost. It is important to incorporate the key suppliers into program planning and development as early as possible so they can participate in design trade studies,

interface definition, and detailed design activities. For these reasons, it is essential to incorporate key suppliers into program planning and development as early as possible so they can participate in the allocation of requirements and design trades as well as resource sharing during the development and detailed design activities. Early identification of key suppliers will facilitate the efficient implementation of process training and requirements flowdown.

8.6.3 Guidance

Key suppliers should be integrated early into the proposal preparation and Integrated Product and Process Development (IPPD) activities to enable the Integrated Product Team (IPT) to take full advantage of their product, system, and process knowledge. Supplier tasks must be fully integrated into overall program plans and schedules and a plan developed which fully describes the supplier management effort. Successful supplier participation in the IPPD process will require effective communication of requirements and goals between the prime contractor and suppliers. It is intended that requirement flow down function in a cooperative fashion between parties. The prime contractor should have an established system for key supplier selection that is based on past performance, proven abilities demonstrated on similar programs, and assessment of the capabilities of key suppliers for the chosen technologies. The system also should address supplier implementation of the practices described in this Manufacturing Development Guide.

The use of Government Furnished Property, Equipment, Services, and Facilities (GFP) represents a special area of focus in the treatment of key suppliers. Communication and teamwork between the prime contractor and key GFP suppliers must be fostered. This will require the government to assure that its contracts with key GFP suppliers and the prime contractor allow Associate Contractor Agreements (ACAs) which expedites communications in areas such as interface requirements, changes in design, risks, and schedules. Past programs have often been hampered by slips in delivery and integration problems with the key GFP when requirements and interfaces were not effectively communicated to the key GFP supplier. The supplier management plan prepared by the prime contractor should address incorporation of key GFP supplier activities and schedules into the overall program plan. If an ACA is implemented on a program, the agreement must provide for the participation of the key GFP contractors in the IPPD Team arrangements, and must allow sufficient prime contractor insight into key GFP contractor activities to permit effectively integrating them into the Integrated Master Plan (IMP).

8.6.4 Lessons Learned

Programs that have not successfully integrated their key suppliers into the program have had difficulties in meeting their requirements and goals. Past practices often neglected the supplier base until after concepts had been developed and designs begun. This has led to problems whenever supplier product and process capabilities were insufficient compared to predicted performance and allocated needs. System integration was often hampered by interface difficulties and the prime contractor often had little insight into supplier risk areas. Past performance data relative to suppliers was often lacking or given less emphasis than cost in selection activities. Supplier lead times were often optimistically factored in to overall program schedules without sufficient accounting for delays. Inadequate supplier risk assessment tools were available, often resulting in little risk identification and little subsequent mitigation planning.

8.6.5 Recommended RFP / Proposal Content

8.6.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 "Suggested EMD Statement of Objectives (SOO) Content."

8.6.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Flowdown of key characteristics process and key product characteristics to responsible suppliers.
- Identification of key suppliers, including suppliers of GFP, and integration of supplier activities into the overall program plan.
- Early supplier participation in IPTs.
- Participation of GFP contractors in IPTs (via ACAs).
- Identification, analysis and management of supplier risk.
- Integration of supplier risk management plan into the overall program risk management plan.

8.6.5.3 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

- Key suppliers identified and selected and subcontracts negotiated.
- Key supplier concurrence with requirements allocation and flowdown accomplished.
- Key supplier identification of key product characteristics. (See Chapter 7, Section 7.6).
- Associate Contractor Agreements finalized with GFP suppliers.
- Supplier Manufacturing Capability Assessment (MCA) (See Chapter 7, Section 7.4 "Manufacturing Capability Assessment and Risk Management") performed and results presented for suppliers not previously evaluated.

Interim Event (corresponding to historical Critical Design Review):

- Key supplier detailed designs complete.

- Key supplier identification of key process parameters complete. (See Chapter 7, Section 7.6).
- Key supplier preliminary process specifications complete.
- Key supplier risk assessment input provided to prime contractor.
- Key supplier events/activities included in IMP.

Interim Event (corresponding to historical System Verification Review):

- Key supplier designs documented and baselined.
- Final specifications for supplier processes completed.
- Key supplier risk assessment completed.
- Key supplier events/activities included in IMP.

8.6.5.4 Contract Data Requirements List (CDRL) Guidance

- Government Furnished Equipment list.
- Government Furnished Property list.
- Government Furnished Facilities list.
- Government Furnished Services list.

8.6.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for evaluation and selection of key suppliers, including suppliers of GFP.
- Processes for integration of key supplier activities into the overall program plan, including a description of the tasks involved and key events with their exit criteria, to assure that supplier activities support the overall program performance.
- Processes for flowdown of performance specifications and key characteristics.
- Data pertinent to key supplier past performance in areas such as product performance, process performance, manufacturing capabilities, customer satisfaction, and schedule adherence.

- Contractor past performance in the management of supplier schedules and involvement of key suppliers in IPTs.

- Key supplier plans for the implementation of defect prevention processes and techniques.

- Processes for integration of key supplier risk management efforts with the program risk management effort.

8.6.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively Manufacturing Capability and Risk Assessment processes should be based upon:

- The extent to which a disciplined, structured, and defined process is used for evaluation and selection of key suppliers.

- The extent to which a disciplined, structured process is used for the integration of key supplier events and activities into the IMP and for requirements flowdown.

- Effective methodologies for key characteristics and performance specifications flowdown.

- Evidence of past performance in the management of supplier schedules and involvement of key suppliers in IPTs.

- Key supplier experience in (or training plan for) the use of defect prevention processes and techniques.

- Past performance of key suppliers in cost, schedule, quality, and customer satisfaction.

- Key supplier risk assessment and risk mitigation plan.

8.7 Key Characteristics and Processes

8.7.1 Introduction

The identification of key product characteristics and their design margins, and the identification of key production processes and their capabilities, are basic engineering tasks which support manufacturing development. The goal of this practice in Engineering and Manufacturing Development (EMD) is to:

1. Refine and update the list of those characteristics of the design which most influence operational performance:

    - Deletion of product characteristics identified as "key" during Pre-EMD activities due to product redesign to enhance robustness.

- Identification of new product key characteristics as the design matures.

2. Support the identification of production processes that best match the key product characteristics.

3. Enable the development of the required process controls for production.

4. Establish a heritage of those key characteristics that will be most important to future design modification, re-procurement, or second sourcing activities.

Figure 8-11 shows how this practice area integrates with other practices in the MDG framework.

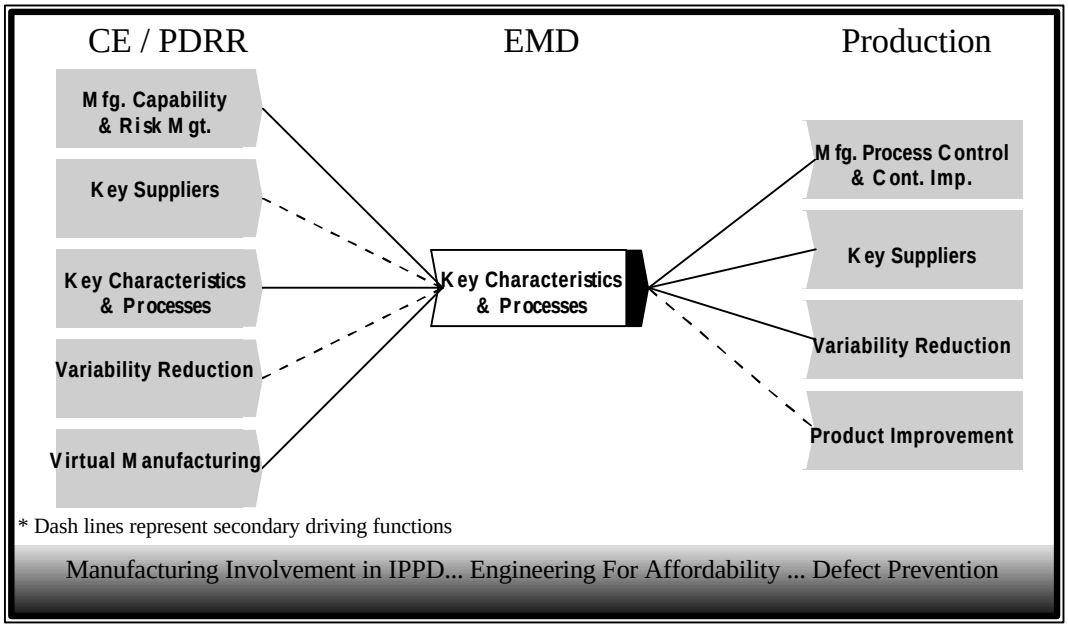


Figure 8-11. How the Key Characteristics and Processes Practice Area Integrates with Other Practices

8.7.2 Rationale

The practice of identifying key product characteristics serves as an important communications tool during product development, design, and production. Key characteristics identification can serve many purposes in support of many different functions. Examples during EMD phase activities include:

- Identifying characteristics that must be specifically addressed during design or modification trade studies because of high system sensitivity to characteristic variations.

- Identifying characteristics that should be considered for redesign in order to reduce the sensitivity of that characteristic and achieve a more robust product design.

- Identifying characteristics that may represent the highest payoff for life cycle affordability and performance trade studies.

- Identifying characteristics against which the application of defect prevention based design and manufacturing tools would be beneficial.

- Identifying characteristics for which manufacturing process capabilities should be assessed (see Chapter 8, Section 8.4 "Manufacturing Capability Assessment and Risk Reduction").

- Identifying characteristics for which process control data collection and variability reduction activities should be considered (see Chapter 8, Section 8.8 Variability Reduction).

- Identifying characteristics that will probably require product/process validation to satisfy the manufacturing risk management plan (see Chapter 8, Section 8.10 Product and Process Validation).

- Identifying the product characteristics that are most important and that may require extra attention in the manufacturing and quality assurance processes

- Helping to ensure consistent product quality through re-procurement and/or second sourcing activities.

Identification of product key characteristics, and associated processes and process parameters, should begin in the Concept Evaluation phase and continue throughout EMD, but there is value to be gained from instituting the key characteristics identification program during EMD (or even during Production). Early identification of key characteristics provides the opportunity to address potential production problems before the product is designed, and tooling and test equipment are committed. This permits the consideration of product design trade studies for improved robustness or new process development before a schedule crisis occurs.

Clearly the practice of identifying and qualifying key production characteristics and processes is a productive way to make the transition to production smoother, so that subsequent process improvement efforts can be directed to control cost and quality.

8.7.3 Guidance

To minimize the risk of transition to production, and to control product cost and quality during production, it is essential to identify, quantify, qualify, and control key product characteristics through the control of the associated key process parameters. There are three essential steps in this practice: (1) identification of key product characteristics; (2) identification of key production processes; and (3) identification of the key process parameters. Completion of

these steps permits efficient application of many of the tools discussed in this guide, along with other design tools associated with defect prevention, by narrowing the focus to those characteristics and processes which will benefit most from their application. It is essential that these practices flow down to key suppliers whose products will have an effect on the contractor's attainment of key design features and key system requirements.

The identification of key process parameters should flow logically from the identification of key product characteristics. Drawing standards should provide for identification key product characteristics, design margins for key characteristics, and flow down of requirements to all critical items. A recommended method for the identification of key characteristics on drawings is the use of a key characteristic "flag," such as: Key. Key production processes will then be those processes associated with controlling the product key characteristics. Development, Design, and Fabrication Specifications (see Chapter 8, Section 8.4, Specification and Standards Management) should reference key product characteristics and their associated key process parameters. Specific process operations and procedures may be contained in reference documents to protect proprietary processes.

The key characteristics identification process is best implemented in an Integrated Product Team (IPT) environment. It requires effective internal flowdown and total supplier involvement. A documented method for the identification of key characteristics, such as the use of Pareto and/or Quality Function Deployment (QFD) techniques (see Chapter 7, Section 7.4, Manufacturing Engineering's Role in IPPD) should be established that considers product performance impact and sensitivity to variation. Other tools that are useful in identifying key characteristics include historical data on similar manufacturing processes and tools and the Loss Function method of assessing the loss (in either performance or dollars) resulting from a characteristic's deviation from nominal variation. This is shown graphically in Figure 8-12 (note that loss functions are not necessarily symmetric about the nominal, as shown in this example). One criteria that is often used is to declare a characteristic "key" if the magnitude of the slope of the loss curve is 1 or greater within the specification limits.

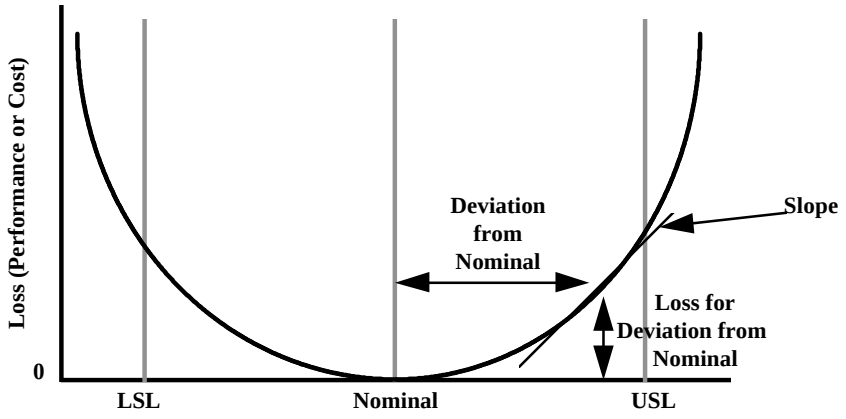


Figure 8-12. Loss Function

Figures 8-13 and 8-14 demonstrate the top-level and detailed flows of the key characteristics identification process, and serve to establish the standardized nomenclature that will be used throughout this document. It is also important to think through the life cycle of the product so that characteristics related to field supportability are identified as well as those related to system performance characteristics.

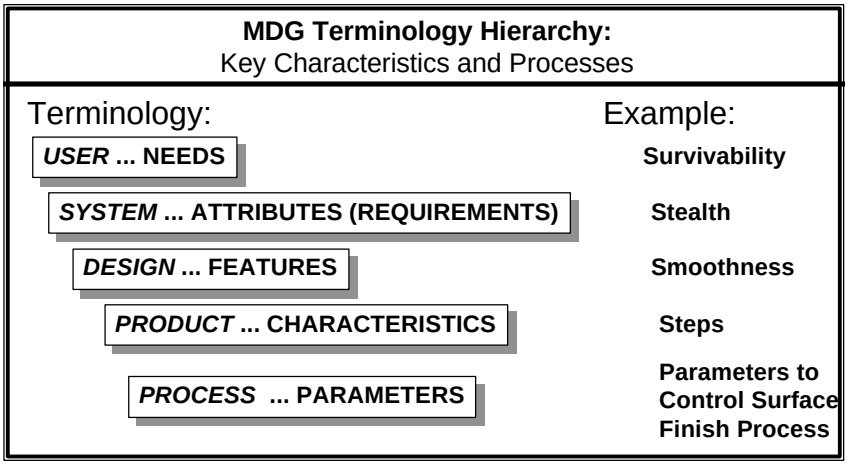


Figure 8-13. Key Characteristics Terminology

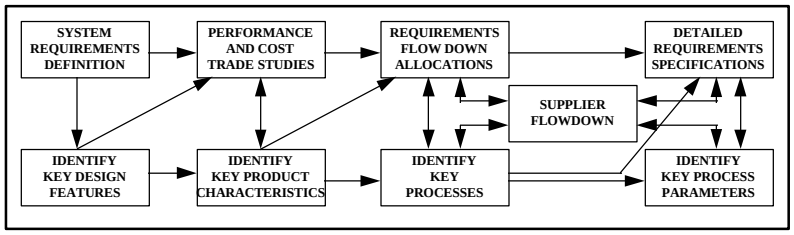


Figure 8-14. Key Characteristics Process Flow

The proper implementation of key characteristics must encourage changing the focus from the trivial many characteristics of a system to a manageable set of the vital few characteristics (and related process parameters) whose control will provide the desired weapon system cost, performance, and quality. Attention can then be given to balancing these vital areas of product and process design in order to arrive at a robust design. When balanced, robust designs are not achieved, this approach will permit proactive steps to managing the vital few characteristics during production.

Key characteristics are identified conceptually, validated and then flowed to the responsible IPTs to be carried into the product and process documentation. Target values and tolerances are established as a part of rigorous error budget and tolerance flowdown analyses, in conjunction with process development, to provide product/process matching. The key product characteristics are evaluated during the Manufacturing Capability Assessment and, if necessary, can be further addressed as part of variability reduction and manufacturing risk management activities. Effective flowdown of key characteristics to suppliers, and the key characteristics identification process, are

essential to maintain effective supplier communications and to ensure the success of future variability reduction activities at all levels.

The identification of key characteristics is a team effort requiring personnel familiar with the operational concept, system concept, system design, performance requirements, production concept, and support concepts. Sensitivity analysis of key product characteristics to process variations may be performed and, if necessary, development tests may be performed to verify the relationships between key process parameters and key product characteristics. An easily audited documentation trail for the key characteristics identification process should be established and maintained throughout the program.

To easily verify the requirements associated with key production processes, it will be necessary for the contractor to provide a clear documentation trail which allows identification of the process key parameters from product key characteristics. It will also be necessary for the contractor to establish a verification matrix which documents the efforts required to verify process capabilities and control requirements, as well as the results of these efforts which support the ability of the processes to meet all product key characteristics and requirements. The matrix should include those characteristics to be verified by inspection and test, as well as those by statistical control techniques. This documentation trail will be used in the Manufacturing Capability Assessment (see Chapter 8, Section 8.5, Manufacturing Capability Assessment and Risk Management) to verify process capabilities.

8.7.4 Lessons Learned

The benefits of implementing defect prevention and manufacturing development tools and techniques have been well demonstrated at both commercial and defense-industry companies. However, the cost of doing so for some characteristics and associated process parameters outweighs the benefits received. The identification of key characteristics avoids the unnecessary implementation of tools such as Statistical Process Control and other variability reduction tools over the entire set of parameters associated with a production system.

The key characteristics identification approach provides a means of achieving variability reduction benefits without exceeding reasonable data gathering and tracking capabilities. As an example, a typical high rate production missile program may involve thousands of measured parameters, hundreds of in-house processes, hundreds of supplier processes, and hundred of units per week production rate. Attempting to apply variability reduction techniques to one hundred percent of the process parameters would require tracking and controlling millions of measurements per month. The use of statistical reporting methods coupled with the limiting of tracked processes/parameters to a “vital few” key product characteristics and process parameters is normally the most cost and schedule effective approach.

The contractor should apply the same discipline and effort to the qualification of the production processes as for the performance of the product. By identifying the key product characteristics and key process parameters, risks can be avoided or mitigated and the transition to production simplified. This, in turn, will allow subsequent process improvement efforts to be

focused on cost reduction and continuous improvement rather than on struggling to meet production schedules.

8.7.5 Recommended RFP / Proposal Content

8.7.5.1 System Specification Requirement

Key Characteristics and Processes: Requirements for key product characteristics and process parameters identification will be included in all Complex Item (CI) Design Specifications. Key process and key process parameter specifications will be referenced in the applicable Development, Design, and Fabrication Specifications. Key processes are defined as any processes which control key product characteristics.

Drawings: Drawings will identify key product characteristics. Key product characteristics are defined as those characteristics that have the greatest influence upon the product fit, performance, or service life.

8.7.5.2 System Specification Verification

Key Production Processes: Specific verification requirements shall be identified for each process key parameter in the appropriate CI Fabrication Specification. In general, verification of the identification of process key parameters shall be accomplished through analysis and inspection.

8.7.5.3 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 “Suggested EMD Statement of Objectives (SOO) Content.”

8.7.5.4 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror’s proposed program:

- Identification of key product characteristics, as design matures, that influence design performance, design affordability, and design quality.
- Reviews of product key characteristics identification with respect to product design trade studies and process development activities.
- Processes which balance product design requirements with manufacturing process capabilities.
- Development and maintenance of CI specifications that satisfy the System Specification requirements.
- Identification of key process parameters.

- Processes for documentation of key characteristics, processes, and parameters on drawings and in appropriate process specifications.

- Development and maintenance of tolerance flowdown and error budgets for each key characteristic.

- Flowdown of product key characteristics and processes to responsible suppliers.

8.7.5.5 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

- Identification of preliminary key product characteristics complete.

- Identification of preliminary key processes complete.

- Flow down of key process requirements complete.

- Drawing system/standards and drawing release criteria defined prior to start of detailed design.

Interim Event (corresponding to historical Critical Design Review):

- Final key product characteristics determined.

- Final key production process parameters determined.

- Preliminary specifications for key processes developed.

- Rationale provided to support the detailed design of product, Special Tooling, Special Test Equipment, and Support Equipment (ST/STE/SE), including matching of product design requirements to manufacturing process capabilities, production cost assessments and sensitivity of key product characteristics design margin to off nominal production, design robustness balancing. Details to include the results of key supplier efforts.

Interim Event (corresponding to historical System Verification Review):

- Final specifications for all key processes developed.

- System defined by CI Development/Design/Fabrication specifications to meet all system requirements.

- Preliminary Build-to documentation complete including identification of key characteristics.

Milestone III (Approval to Enter Production):

- Final Build-to documentation complete including identification of key characteristics and control plans for key characteristics.
- Contract Data Requirements List (CDRL) Guidance

Prime Item Product Development Specification.

- Prime Item Product Design Specification.
- Prime Item Product Fabrication Specification.
- Approved Technical Data Package at Milestone III.
- Verification matrix at MCA. This item should be made available, upon request, as informal Data Update Events (DUE)
- Information copies of product definitions, specifications, and Technical Data Package. This item should be made available, upon request, as informal Data Update Events (DUE)

8.7.5.6 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Detailed description of a design system which includes identification of key product characteristics, identification of key production processes, balancing of key product design requirements to production process capabilities, identification of key process parameters and verification methods.
- The availability of established and validated process control tools and practices.
- Data pertinent to prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

8.7.5.7 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Key Suppliers practices should be based upon:

- The extent to which a disciplined, structured, and demonstrated process is used for requirements allocation and identification of key product characteristics, key process parameters, and product/process matching.
- The availability of established and validated process control tools and practices.

- Evidence of prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

8.8 Variability Reduction

8.8.1 Introduction

Variability reduction (VR) efforts during Engineering and Manufacturing Development (EMD) are intended to lay the foundation for continuous improvement in product quality and in manufacturing process efficiency. The main focus of EMD VR activities is to: (1) support the Manufacturing Capability Assessment (MCA) and product/process matching effort; (2) develop the tools and processes for conducting a successful VR program during Low Rate Initial Production (LRIP) and Production; and (3) implementing these tools and processes during LRIP build activities. The contractor should apply the same level of discipline and effort to the qualification and quantification of production process capabilities as has historically been applied to verifying the performance of the product.

The VR effort has no direct requirements in the System Specification and no specific deliverable data items need be generated. Rather, it represents tasking that the contractor should identify in the Statement of Work (SOW). The results can be reported through normal program status documentation.

Figure 8-15 shows how this practice area integrates with other practices in the MDG framework.

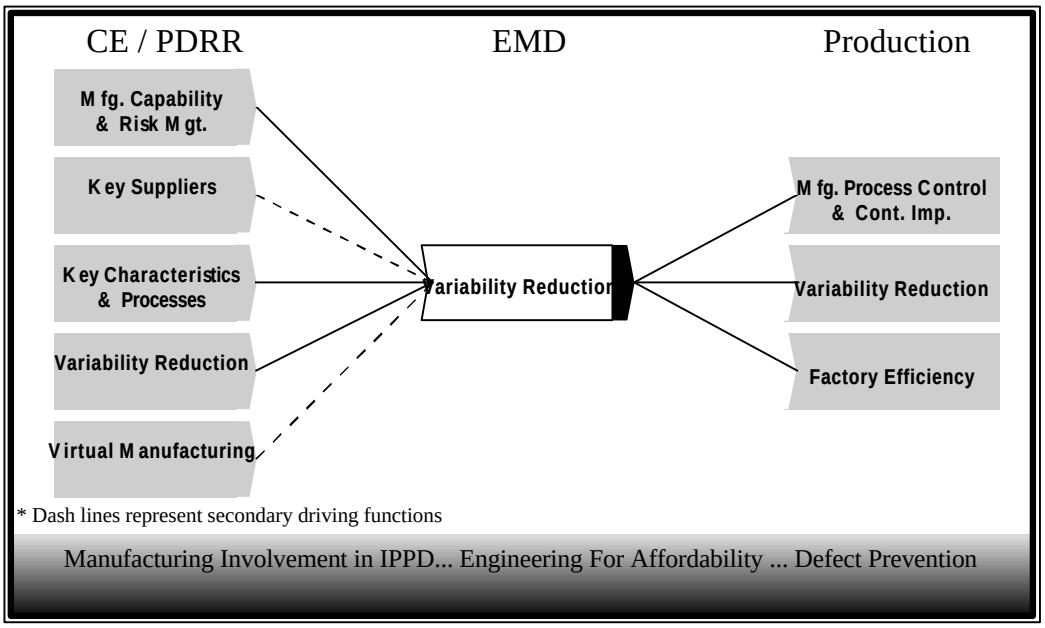


Figure 8-15. How the Variability Reduction Practice Area Integrates with Other Practices

8.8.2 Rationale

Variability reduction is a systematic approach to reducing product and process variability in order to improve cost, schedule and performance. It introduces the idea that just falling within specification limits (goal-posting, pass/fail, attribute testing) is not the best measure of quality. Rather, the variability of a key process and its relationship to process capability becomes a measure of merit. This benefits both the supplier and customer. For the customer of weapon systems which will be in the inventory for decades, the reduction in parts variability can provide significant paybacks in reducing "infant mortality" problems, improving the performance of components and the overall weapon system, reducing spares and support equipment requirements during field introduction, lowering repair costs, improving durability, and extending overhaul intervals. All of these improvements have a significant impact on reducing operations and support costs as well as improving operational availability and capability. For the supplier the benefits include improved yields, more reliable scheduling, reduced cycle times, reduced scrap and rework, better cost control, improved competitiveness, and improved customer satisfaction.

A vital element of a successful variability reduction program is identifying the key characteristics and process parameters (see Chapter 8, Section 8.7, Key Characteristics and Processes) design margins, and performing product/process matching to ensure an acceptably high process capability index (C_{pk}) is achievable. (See Chapter 7, Section 7.6, Variability Reduction, for a detailed discussion of capability index and guidance on calculating the C_{pk} of a process.) The design margins, balanced design, should be the logical result of design trades using methodologies such as design tolerance analyses, error budgeting, and design for manufacture and assembly.

In defining the process capability and process control requirements it should be assumed that they will be achieved through a combination of process control and inspection, and in general, lower production costs can be achieved by utilizing effective process control techniques, which eliminate the need for many of the conventional quality inspections and tests.

8.8.3 Guidance

A notional view of the underlying logic for an EMD Phase VR program is shown in Figure 8-16. The VR effort should start with, but not narrowly focus on, processes which have been identified as "key processes." VR represents a quality philosophy with broad applicability. When fully implemented it should push down the decision making authority to the lowest levels consistent with the requirement to maintain adequate control of the product. It will require a cross functional support team, or Integrated Product Team (IPT), to adequately evaluate and implement potential changes efficiently. One very important aspect of a robust VR program is the flowdown and implementation of VR practices at all supplier levels.

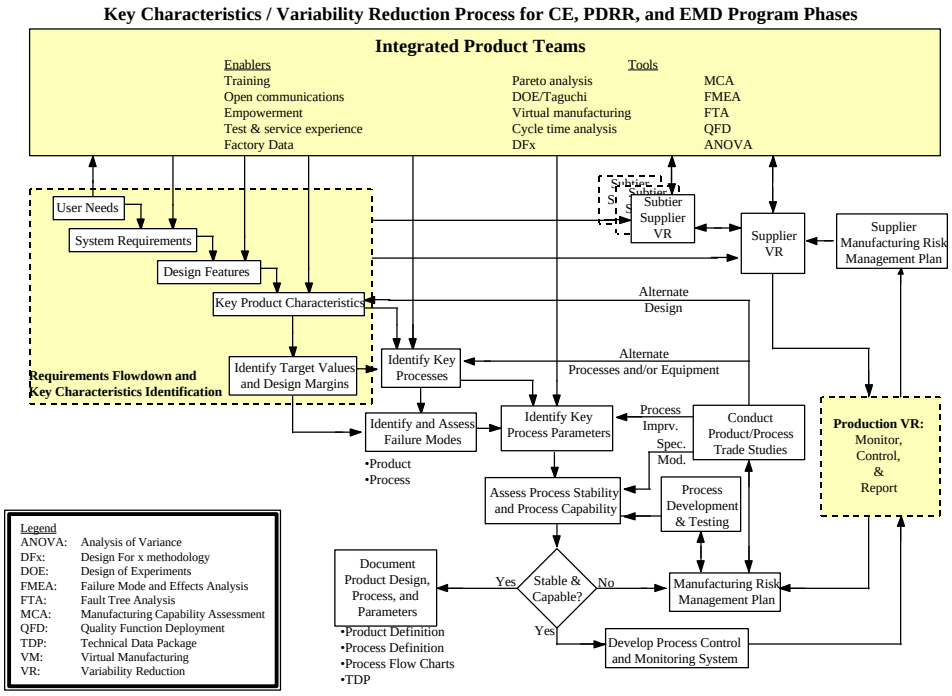


Figure 8-16. Logic Flow for EMD Phase Variability Reduction

Key elements of VR are a well defined process that encourages and empowers the factory workers and the supporting management infrastructure. The techniques associated with process control and on-going evaluations of process capability will identify candidates for process variability reduction. A major requirement for implementing this practice would be maintaining the IPT membership to fully support changes to product designs and/or processes. Since a majority of the actual "production" on any system is accomplished by the prime contractor's suppliers, it is essential that this requirement be effectively flowed to the key suppliers.

The initial VR effort should be to define a methodology for the evaluation of product quality and production process stability and capability and the matching of product design requirements to process capability, and assessing the potential benefits resulting from proposed process or design improvements. Where applicable, the use of statistics-based process control methods should be the standard, with a capable process defined as one with a minimum process capability index of 1.33 or greater. For safety-critical, and sometimes for mission-essential capabilities, acceptable values of C_{pk} could exceed 2.0, and it may not be either practical or cost effective to rely solely on process control to verify conformance. In these cases, it will still be prudent to assure process control to minimize the resultant cost of scrap and rework, but it may also be necessary to require final inspection of critical parts. Mandatory inspection will be minimized as sufficient confidence in the quality program and application specific process controls is achieved.

Verification of process capability and control will be in accordance with the appropriate development specification. It will be essential for the contractor to develop adequate verification requirements for the key processes as they are identified. The establishment of the process capability and control requirements will be accomplished through a combination of analysis and

synthesis as part of the design trade process. Verification of process capabilities, including Special Tooling and Special Test Equipment (ST/STE), also requires verification of the process control requirements and any required inspections/test capabilities. As the product design evolves during the design trade process, the initial assessment of process capabilities may be based on historical data. For processes which have not demonstrated the required capability, it will be necessary to use experience developed during the build of test articles, and possibly dedicated process demonstrations, to verify process capability and control. Technology demonstrations, process development activities, and risk mitigation plans must address process capability understanding and affordability implications as part of the risk closure events exit criteria.

The use of variables data rather than attributes data should be strongly encouraged. Variables data has a number of inherent advantages. It provides greater insight into actual process performance, It permits the detecting of adverse trends before a non-conformance is actually produced, And it is valid with smaller sample sizes.

8.8.4 Lessons Learned

Experience has shown that variability reduction represents a significant cultural change over historical practices. It has been successfully implemented through IPTs empowered with the responsibility for identifying and correcting production and design-related problems. (These IPTs have included a full range of functional support with the ability to resolve problems, including preparation of configuration control change proposals.) In addition to product IPTs, it has also been proven effective to form a system level IPT which can address problems that cut across the boundaries of the smaller teams. This has proven especially useful in finding and resolving root causes for problems at the interfaces of the various sub-assemblies. In some cases, all sub-assemblies meet final requirements at that level but do not properly function when joined with other subassemblies. This is frequently a problem of misidentified or unidentified requirements which need to be addressed at the system level, or of inadequate tolerance funneling.

The concept of robust design is a useful adjunct to traditional process control and variability reduction efforts. It optimizes the selection of design parameters so that performance is less sensitive to sources of variation in manufacturing or in the product use environment. With this approach to design, it is not always necessary or appropriate to directly address the root cause of variation if a sufficient countermeasure is available to offset the effect of that cause. When planning the control and verification of state-of-the-art materials and processes, it is important to understand process capability limitations. It may be beyond the current state-of-the-art to achieve C_{pk} of 1.33 or 2.0. What is critical is to establish what the process C_{pk} is, and also to assure the stability of the process so that output is consistent and predictable to enable effective balancing of the design with the process capability. During production, quantification of that understanding may even require inspection to assure conformance to some key product characteristics. In such cases, the variability reduction activity will be a necessary element of quality planning.

8.8.5 Recommended RFP / Proposal Content

8.8.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 "Suggested EMD Statement of Objectives (SOO) Content."

8.8.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Determination and documentation of design margins, process capability requirements, and process control requirements for key processes and process parameters.
- Matching of product design requirements to manufacturing capabilities during the product definition process.
- Development and demonstration of methods for evaluation of process stability and capability, and for assessment of the potential for quality improvements to the product design and production processes.
- Creation and maintenance of a key characteristics/key parameters verification matrix.
- Key supplier development, implementation, and maintenance of a VR methodology encompassing all key characteristics for which they are responsible.

8.8.5.3 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Critical Design Review):

- Program VR methodology and management philosophy defined.
- Program VR methodology ready to implement in LRIP.

Milestone III (Approval to Enter Production):

- Organizational structure demonstrated for implementation of VR.
- Change control process defined.
- Rationale provided for contractor's program approach to VR and how it provides intended results.

8.8.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

8.8.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Approaches to variability reduction, product/product matching, and process control.
- intended metrics and the rationale for the use of attributes data, if proposed in lieu of variables data
- Evidence of the availability and use of process control tools and techniques
- Planning for key supplier flowdown of VR methods and requirements.
- Data pertinent to prime contractor and key supplier past performance in variability reduction, product/process matching, and process control.

8.8.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Variability Reduction processes should be based upon:

- Evidence of prime contractor and key supplier past performance and capabilities in variability reduction, product/process matching, and process control.
- Maturity of the VR process as reflected in the intended metrics and the selection of variables versus attributes data.
- Availability of established and validated process control tools and practices
- Availability of personnel, at prime contractor's and key supplier's facilities, trained in variability reduction and process control techniques; and/or availability of effective training resources.

8.9 Long Lead and Non-Recurring Activities

8.9.1 Introduction

In today's acquisition environment, long lead items and non-recurring activities are issues in the Engineering and Manufacturing Development (EMD) phase of the weapon system program rather than the Production phase. Because Low Rate Initial Production (LRIP) is moved forward to EMD by the new acquisition management initiatives (DoD Directive 5000.1 and DoD Regulation 5000.2-R), the long lead and non-recurring activities required to support initial production are relocated as well.

In the previous acquisition environment, these efforts were usually part of a separate contract or part of the production contract which ran in parallel with the development effort. Their

funding, therefore, traditionally came from outside the development budget. Although a single contract may now be used for both development and long lead/non-recurring items, different types of funding (that is, development funding and production funding) will still be used for each. Currently there is no expectation of a change in policy to allow a single funding type to cover both LRIP and the basic EMD requirements.

A key objective in the new acquisition environment is the incremental demonstration of production process capabilities early on by maximizing the use of final production processes, equipment, tooling, and test equipment in the development phase. This requires the program to focus much earlier on many issues that were traditionally part of non-recurring activities in the production phase. The verification process culminates in LRIP, which now occurs at the end of the development phase.

To ensure compatibility between the tooling requirements, the in-process/final test requirements, and the product design, for instance, Special Tooling and Special Test Equipment (ST/STE) are designed in parallel with the product in the new environment. Similarly, Support Equipment (SE) design, development, and verification must now be accomplished in parallel with the product design in order to ensure the compatibility of the support equipment when it is ultimately fielded. The use of a common database for both product and production tooling reduces the risk of mismatch or incompatibility. The effective simulation of manufacturing and support equipment in the pre-EMD phases provides a baseline against which to evaluate the actual design during EMD, and the simulation tools are expected to significantly reduce tool redesign and rework.

The guidance provided in this section does not apply to the acquisition of long lead items authorized by Congress to protect production schedules. These acquisitions rely on advance procurement funding. (See AFFARs 5317.91, dated April 9, 1993, for policy on this subject.)

Figure 8-17 shows how this practice area integrates with other practices in the MDG framework.

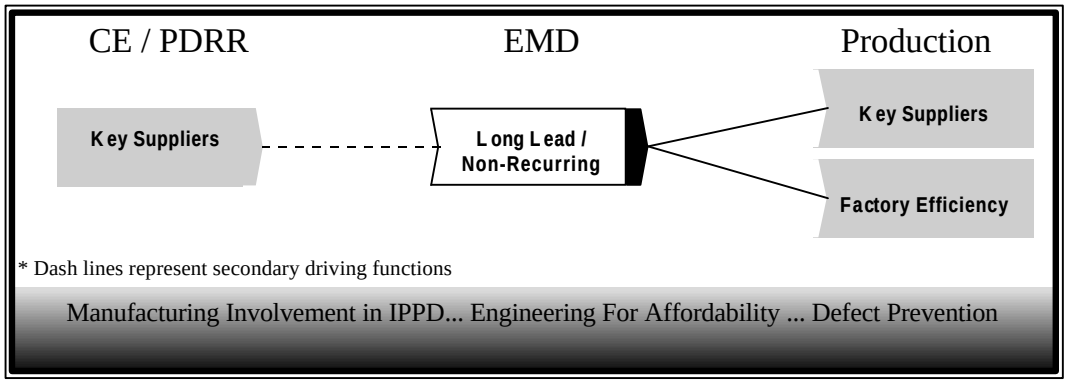


Figure 8-17. How the Long Lead/Non-Recurring Activities Practice Area Integrates with Other Practices

8.9.2 Rationale

The verification of production process capabilities, and the non-recurring efforts required to design, fabricate, test and deliver ST/STE for production, should be part of the preliminary manufacturing plan and the Integrated Master Plan (IMP). The cost of ST/STE may thus be an appropriate consideration in the design trade studies. In addition, with LRIP now serving as the culmination of the EMD effort, all long lead orders must be placed and all traditional non-recurring activities must be completed in time to acquire the materials and components needed for initial production.

Even the verification of SE requirements and the development of the equipment itself is now a part of the development effort as well, and takes place in tandem with the product design to ensure the supportability of the fielded system. The process flow simulations and assembly simulations performed for risk reduction by the IPT's manufacturing engineering function during pre-EMD should therefore be documented in support of these activities.

8.9.3 Guidance

The level of effort required for long lead items and non-recurring activities will depend on the program direction and on the level of risk associated with the selected production processes, whether or not new or significantly improved production processes are required. The contractor should plan for the design and acquisition of all long lead materials and ST/STE required to support the prototype/test article build and LRIP. The equipment required and the process development and maturation factors incorporated in the risk reduction manufacturing process flow simulations will be reflected in this process. The IMP should provide a rationale to establish the timeliness of equipment and materials.

The contractor should structure the program effort to provide incremental verification of production process capabilities during EMD. With LRIP culminating the EMD phase, initial production should provide a final verification of production capabilities, including long lead items and those non-recurring efforts required to design, fabricate, test, and deliver the ST/STE for production. The cost of this equipment should be considered in the design trade studies. Similarly, development and verification of SE requirements is essential to ensuring the supportability of the fielded system. Effective simulation of the process flow, with a careful focus on both production and supportability issues, should be an integral part of the contractor's Integrated Master Plan.

8.9.4 Lessons Learned

With the downsizing of the defense industrial base, the identification of long lead issues increases in importance. The program plan for LRIP which is developed in the PDRR phase must address the need to have ST/STE available for LRIP. The inclusion of items identified as high risk in the IMP and program schedule has effectively allowed program management to focus on the most critical items. Experience with successful recent programs indicates that those which effectively meet both cost and schedule objectives have done so in part through paying careful

attention to long lead items. The use of commercial off-the-shelf products and the reuse of test equipment and software have also contributed to the success of these programs.

8.9.5 Recommended RFP/Proposal Content

8.9.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 "Suggested EMD Statement of Objectives (SOO) Content."

8.9.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Long lead items incorporated in the preliminary manufacturing plan and the IMP.
- ST/STE/SE (required to support the test article build plan, line proofing, process verification, and LRIP) incorporated in preliminary manufacturing plan.

8.9.5.3 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

- Long lead items identified.
- ST/STE/SE requirements identified.

Interim Event (corresponding to historical Critical Design Review):

- LRIP Plan includes long lead item acquisition and ST/STE availability for LRIP.
- Risk management planning addresses long lead items.
- EMD funding sources support non-recurring needs.

8.9.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

8.9.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

- The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following: The timing of and need for long lead and non-recurring equipment and activities.
- The relationship of ST/STE/SE to key characteristics and key processes.
- The rationale for key events which support the exit criteria.

- ST/STE/SE development in parallel with and as an integral part of development of the prime item.

8.9.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage long lead and non-recurring activities should be based upon:

- An LRIP production plan and schedule which address long lead items, ST/STE/SE, and capital requirements to support LRIP activities occurring in EMD.
- LRIP production planning which supports key characteristics and key processes.
- Identification of and planning for long lead items.
- Risk management planning integrated into IMP and IMS.

8.10 Product and Process Validation

8.10.1 Introduction

Because today's acquisition environment emphasizes the benefits of early, incremental verifications of producibility and of production capabilities during the development phase of an acquisition program, the proper applications of product and process validation in today's environment deserve careful consideration. Traditionally the Line Proofing process has been the surest means of demonstrating factory capabilities, with actual production tooling and a first set of parts used to build an actual product or product component late in EMD as part of the transition to production. In this context, line proofing has served a number of important purposes: verifying the final build-to package; verifying the capability of ST/STE; testing factory operations; verifying fault detection capabilities; and providing the systems integration and test experience required to produce the end product. A structured line proofing approach was also valuable because it allowed iterative build, test, analysis, and improvement cycles to affect the design and build processes.

The rapid development of newer, more effective virtual manufacturing and virtual assembly tools, however, now makes it possible to accomplish many of the product and process validation objectives once provided by line proofing earlier and less expensively. Often incremental verification achieves the same objectives without going to the lengths required by the use of actual production tooling and parts. A structured approach to incremental verification, simulation-based risk reduction, and virtual manufacturing makes it possible to check out and verify the entire production process and the supporting infrastructure, thus almost totally eliminating first unit rework and the classic transition, early production, and build-up problems.

Determining whether a process like line proofing is called for in today's acquisition environment requires an analysis of the extent to which virtual manufacturing processes might provide a better demonstration of production capabilities, and more cost, schedule, and performance benefits.

Figure 8-18 shows how this practice area integrates with other practices in the MDG framework.

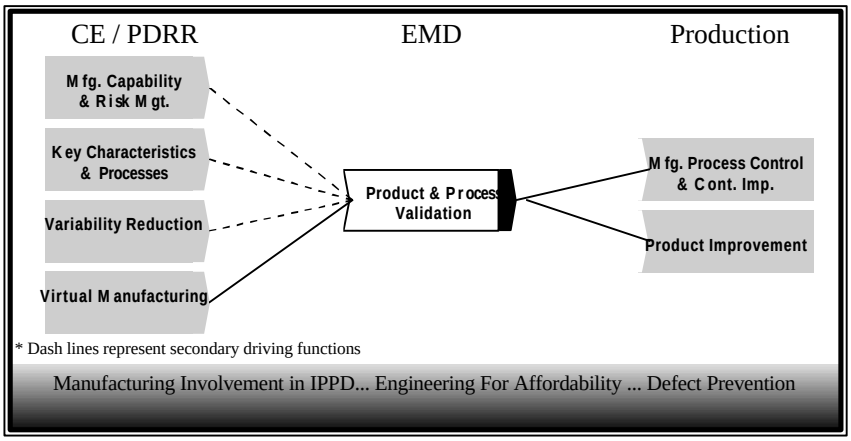


Figure 8-18. How the Product and Process Validation Practice Area Integrates with Other Practices

8.10.2 Rationale

Today's incremental verification and validation approaches mean that the decision to require any form of traditional product and process validation such as line proofing, and the determination of the extent of such an effort, should be tied to special factors such as high production rates, innovative processes, ST/STE/SE challenges, special production transition problems, or other identified risks which call for definitive resolution in a production environment. The magnitude of the product and process validation effort, whatever form it takes, will depend on the availability of resources, the maturity of processes, and the extent to which real or simulated production processes were employed to build test articles during EMD.

8.10.3 Guidance

The main objective of the product and process validation effort is to reduce risk by verifying both the direct and indirect infrastructure required for production prior to the start of the actual production articles. For maximum usefulness, the product and process validation line proofing effort should consider whether the LRIP/prototype/test articles were produced (or simulated) in the final production assembly area, the extent and level of success of similar production efforts at the same facility, the extent of new or modified equipment required for production, and the stability of the infrastructure which supports production.

8.10.4 Lessons Learned

The recognition of the need for more effective risk management earlier in the acquisition program (and the development of new tool sets like virtual manufacturing) has changed product and process validation from an end-of-the-process scenario (where the tooling, test equipment,

and product design are evaluated in an actual LRIP build) into a process which verifies and validates some items in a synthetic environment, and others incrementally throughout the design cycle. Experience with more recent programs employing MDG principles indicates that first time product success is usually a result of both synthetic and real testing of new materials, designs, and processes.

8.10.5 Recommended RFP/Proposal Content

8.10.5.1 Government Statement of Objectives (SOO)

See Chapter 8, Section 8.1.1 "Suggested EMD Statement of Objectives (SOO) Content."

8.10.5.2 Contractor Statement of Work (SOW) Content

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- The appropriateness of the effort to the program considering the availability of advanced production capability demonstration resources.
- The inclusion of teammates and major suppliers in the production and process validation effort.
- The use of production and process validation to verify the build-to documentation and demonstrate the capability of the ST/STE and the processes, plans, and facilities for initial production.
- Distinctions between prototype facility processes and production facility processes.
- The scalability of any prototype facilities employed.

8.10.5.3 Integrated Master Plan (IMP) Exit Criteria

Interim Event (corresponding to historical Preliminary Design Review):

- Key product components and processes evaluated from a validation standpoint.
- New processes verified and validated incrementally.
- Additional tests required for verification and validation identified.

Interim Event (corresponding to historical Critical Design Review):

- All ST/STE scheduled for verification and validation before LRIP.
- IMP identifies all open tests.

- Risk management plan identifies all open risk items.

8.10.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

8.10.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- The level of product and process validation effort.
- Simulations and incremental verification and validation processes to proof new tools and processes throughout the development cycle.
- The resources available, the maturity of the products and processes involved, and the level of success of other program events.
- Integration of the line proofing effort into the overall risk management effort.
- Plans for providing guidance on ST/STE/SE validation, and the level of product and process validation effort expected from suppliers.
- Identification of key product and process validation activities in the IMP and in risk management planning.

8.10.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage product and process validation activities should be based upon:

- Incremental verification and validation throughout the design process.
- Integration with the risk management plan.
- Use of simulations for verification and validation in virtual environments.
- Demonstrating producibility and production readiness as well as lowered risk and cost through previous experience with simulation and incremental verification and validation.

9. PRODUCTION PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

9.1 Introduction

The purpose of the Manufacturing Development Guide (MDG) is to promote the development and production of effective, affordable weapon systems through the use of "best business practices" that support the overall acquisition reform initiative. During Production, these purposes are achieved by enabling an environment of continuous improvement in product quality and production efficiency through the application of defect prevention systems, continued supplier involvement in Integrated Product Teams (IPTs), and an effective variability reduction effort. To ensure that affordability and manufacturing issues are fully addressed during the acquisition process, government personnel at the System Program Office (SPO) may wish to use the Contract Data Requirements List (CDRL) guidance and Proposal Instructions to Offerors (PIO) subsections in generating an RFP, and use the Work Statement, Integrated Master Plan (IMP), and Evaluation Criteria guidance subsections in evaluating contractor responses.

These Production phase RFP guidelines are intended to: (1) identify the manufacturing related program technical activities that must occur to promote the production of affordable weapon systems and to reduce the program cost and shorten the schedule; (2) elaborate on the role and responsibilities of Manufacturing Engineering in the IPTs (see Chapter 5); and (3) identify the attributes of a quality system under which these concepts could be fully implemented. Subsequent sections of this chapter provide discussions of the following topics:

- Manufacturing Process Control and Continuous Improvement
- Key Suppliers
- Variability Reduction
- Factory Efficiency
- Product Improvement

The functional relationship of these practices is shown in Figure 9-1.

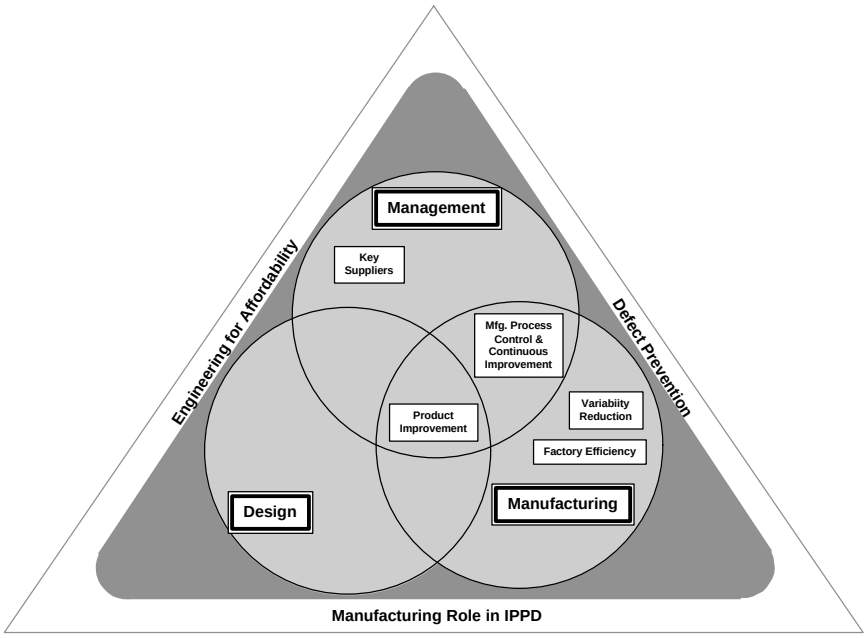


Figure 9-1 Functional Mapping of Production Phase Practices

In each of these sections, specific guidance is provided on Statement of Work (SOW) content, IMP exit criteria, and PIO and evaluation criteria (Sections L and M). In all cases the suggestions should be evaluated and applied as appropriate for a specific program. For example, the Product Improvement practice as described below refers primarily to the incorporation of changes which do not significantly impact form, fit, or function. The implementation of a Single Process Initiative is a good example of this type of product improvement. Major subsystem improvements or Block Upgrades will probably require being treated as an EMD phase activity for the particular subsystems affected, including implementation of EMD phase MDG practices.

9.1.1 Suggested Production Phase Statement of Objectives (SOO) Content

Production Quality and Manufacturing Efficiency. The government's objective is that the contractor implement those processes and systems to assure program affordability through product quality and manufacturing efficiency. The following elements may be considered as appropriate practices for implementation: product improvement initiatives; variability reduction on product and process; manufacturing process control and continuous improvement; use of commercial parts and specifications; use of IPTs; and key supplier relationships.

9.2 Manufacturing Process Control and Continuous Improvement

9.2.1 Introduction

During the production phase of a weapon system program, the responsibility of the manufacturing engineering (ME) function is to focus on the effective control of the manufacturing

processes and on the orderly incorporation of improvements in both product and process[1]. As used here, the term "continuous improvement" refers not so much to improvements themselves, as to the development and implementation of tools and techniques for continuously improving manufacturing processes. Among them:

- Identifying and implementing improvement opportunities in all process areas.
- Establishing a culture in which all employees will be constantly seeking opportunities to make improvements in the tasks they perform and in the ways they perform them.

The analysis and use of data to search for and implement improvement opportunities on a continuous basis should be an inherent part of any continuous improvement culture. Figure 9-2 shows the principal Pre-Production MDG practices that will permit the effective implementation of the Production phase Manufacturing Process Control and Continuous Improvement practice.

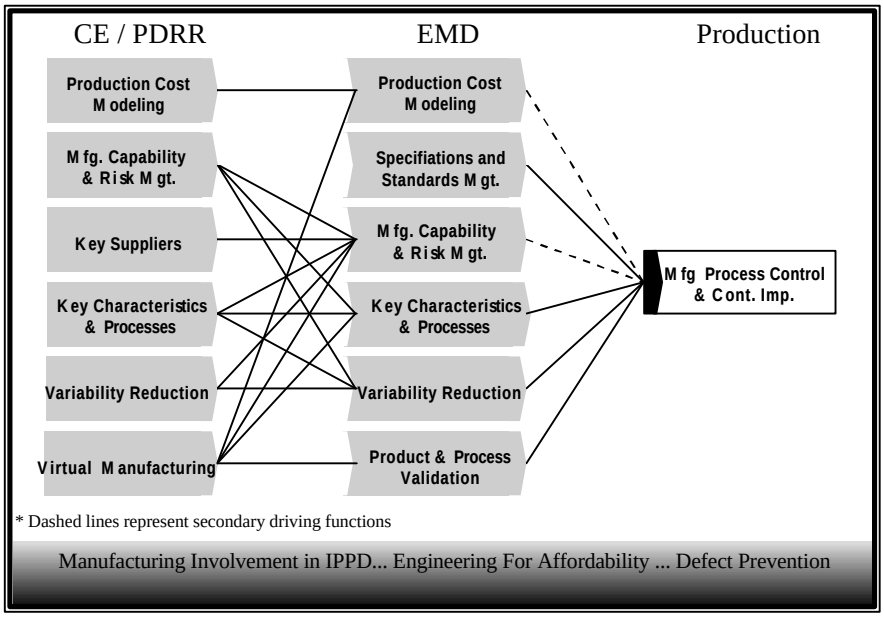


Figure 9-2. How the Manufacturing Process Control and Continuous Improvement Practice Area Integrates with Other Practices

[1] This section focuses on manufacturing process control and improvement in areas other than formal variability reduction (VR) efforts, which are discussed in Chapters 7 and 8 in Sections 7.6 and 8.8. The related subject of product improvement is discussed elsewhere as well: enhancements to conforming product are discussed in Chapter 9, Section 9.6, and the causes of and corrective action to fix non-conforming product are discussed in Chapter 6 on Quality Systems. (Although corrective action systems per se are not discussed in Chapter 6, many other sources of information are available. For example, see Section 4.2.2.10 of the portion of the JACG guide on Defect Prevention Practices).

In today's acquisition environment, contracts should be structured to provide incentives for continuous production phase improvements, schedule gains, enhanced affordability, reduced acquisition cost, and enhanced supportability.

A number of promising concepts and effective techniques related to process control and continuous improvement have been developed in the commercial sector and in the defense industry, including Statistical Process Control (SPC), Taguchi Loss Function, Kaizen, and Pareto Analysis. The JACG Guide on Defect Prevention Practices provides information on these and related topics. Additional information on these subjects is readily available from many sources.

9.2.2 Rationale

The production phase of DoD acquisition programs has frequently been plagued by a cluster of manufacturing problems, usually with one or more of the following contributing causes:

- The lack of effective, systematic process control during production.
- The absence of clear identification of key product features.
- The absence of systematic process improvement efforts.
- The lack of effective cost control.
- The absence of clear incentives for reducing costs during production.

Even with development and design are complete, significant changes may still need to be made in a weapon system program and improvement opportunities are often still available to those who are looking for them. Although product and process designs developed in EMD have been demonstrated and matured in the LRIP phase, lessons learned from development testing and the initial production delivery may point to a need for significant modifications to the design. In addition, quality feedback from process areas may make other improvement needs evident. In fact, both Class I and Class II changes are often needed during the Production phase, with potentially major impacts on performance, producibility, and affordability. Although proper implementation of MDG practices should greatly reduce the need for design changes during the Production phase, some change activity is still likely to be called for.

In traditional product development programs, decisions made during the Concept Exploration (CE) and Product Design and Risk Reduction (PDRR) phases often locked 65% to 75% of the cost into the product, and were difficult–or extremely expensive–to change later. In addition, changes were rigorously controlled by the government Program Office. The effect of this was to ensure that production programs were largely driven by very early decisions made with virtually no manufacturing input.

In today's acquisition environment, however, the contractor has primary control of the detail design and the manufacturing processes. Contractors are responsible for managing their own processes, their own metrics, and their own continuous improvement efforts. In this environment, when an improvement opportunity is identified, the contractor has the authority to go directly to

the process to make corrections, changes, and improvements without requesting government approval. With this authority, however, comes an additional obligation: contractors must be responsible for any changes they may make. The Program Office requires a continuing *insight* into the changes made (as opposed to the historical *oversight* function). The contractor's configuration control of the product and the processes through process documentation, including an audit trail of all changes made, provides a vehicle for the effective functioning of this insight process.

9.2.3 Guidance

In the Production phase the product IPT changes its focus from design and development to production, with manufacturing engineering evolving from a contributing function to a leadership function. This increasing focus on production should ensure effective implementation of manufacturing planning, effective control of manufacturing processes during production, and effective use of continuous improvement methods. The production contract should provide a vehicle for Program Office insight into program management and program status based on the contractor's configuration control of Class II product and process changes.

Manufacturing planning should consider the production flow, the tooling, the ST/STE used to produce the product, operator skill requirements, and quality verification techniques to determine how various processes should be controlled and improvements identified and implemented. Manufacturing planning should be based on the documentation provided in EMD, and on the Program Office insight strategy to be implemented on the production contract. The contract should provide incentives for identifying and making any additional performance or affordability improvements in the design or in processes and production methods. Another consideration which should be taken into account as improvements in processes are implemented is the effect such improvements have on Key Characteristics. Continuous maintenance of the list of key characteristics should be performed as an ongoing part of the improvement process.

9.2.4 Lessons Learned

The value of understanding, measuring, controlling and improving process performance has been demonstrated by numerous companies in both the commercial and defense sectors. A number of major acquisition programs which were under pressure to offset inflation penalties and the cost growth resulting from increased performance requirements have successfully employed formal process improvement measures, often associated with special incentives or recognition. The strong emphasis placed by defect prevention techniques on knowing the process capabilities and generating positive process improvements toward six sigma performance has demonstrated that cost growth can be contained. The linkage of process capabilities to continuous improvement using SPC tools, Variability Reduction techniques, and corrective action efforts has been proven to benefit both cost and schedule performance on programs and major subsystems.

9.2.5 Recommended RFP/Proposal Content

9.2.5.1 Government Statement of Objectives (SOO)

See Chapter 9, Section 9.1.1 "Suggested Production Phase Statement of Objectives (SOO) Content."

9.2.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- The company's process control procedures for manufacturing processes, related documentation, including configuration control of processes and ST/STE, production process flow, and production processes and methods.
- The communication of changes with respect to any of these items and the issue of insight for government representatives.
- Processes for identifying further opportunities for improved performance and affordability.

9.2.5.3 Integrated Master Plan (IMP) Content

Topics which the offeror's IMP should cover include the following suggested areas:

- Continuous collection and periodic review of production and quality data to identify areas for improvement.
- Taking advantage of feasible improvement opportunities identified through production data.
- Tracking of process improvements and changes.
- Processes used in LRIP are documented for use in production, including control methods.
- Configuration control for design documentation provides visibility into changes.
- Manufacturing tooling and ST/STE/SE documentation are under change control.
- Processes and methods documentation are under change control.

9.2.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

9.2.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Methods for manufacturing process control and implementation of continuous improvement.
- Procedures for continuous collection and review of data to identify improvement opportunities.
- Configuration control procedures to be employed for product design, ST/STE/SE, production methods and plans, and manufacturing planning.

9.2.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage Manufacturing Process Control and Continuous Improvement activities should be based upon:

- Demonstrated understanding of the concepts of manufacturing process control and continuous improvement of manufacturing processes.
- Disciplined approach to controlling manufacturing processes, continuously seeking and identifying opportunities for improvement, and implementing process improvements.
- Documentation of past experience/performance in this area.

9.3 Key Suppliers

9.3.1 Introduction

Key supplier partnerships and strategic business alliances have become critical factors in today's defense system acquisitions. Long-term partnerships foster joint commitments between companies and promote shared investments in product improvement and cost reduction efforts. Resource sharing and mutually focused risk reduction activities result in effective problem solving throughout the phases of a program. It is not the intent of these guidelines to promote a business strategy of either exclusive partnerships or sustained competition. Rather, it is to promote active supplier participation in the program teaming structure, thereby allowing the contractor team to exploit complementary strengths to implement cost, schedule, and quality improvements more effectively. Figure 9-3 shows the principal Pre-Production MDG practices that will permit the effective implementation of the Production phase Key Suppliers practice.

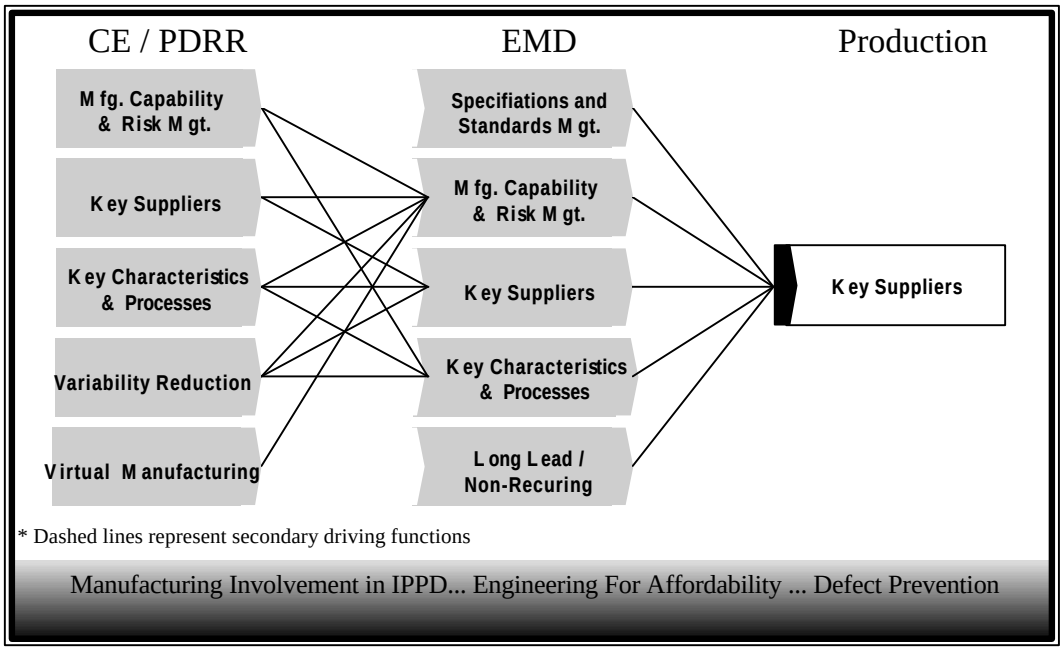


Figure 9-3. How the Key Suppliers Practice Area Integrates with Other Practices

A key supplier, including suppliers of Government Furnished Property (GFP), under the Manufacturing Development Guide (MDG) philosophy, is a supplier at any level whose performance in the areas of cost, schedule, or technical performance, is essential to the development and production of an effective, affordable system. Several criteria t can justify the designation of a supplier as "key." Examples include the following:

- When the requirements flowdown process results in a supplier's product characteristic being essential to maintaining a required system attribute.
- When a supplier is identified as "sole source" because of unique technologies or unique manufacturing capabilities.
- When the supplier's performance is associated with excessive risk, either in cost or technical performance, with no low-risk alternative available.

9.3.2 Rationale

Supplier performance continues to be of great importance during the production, support, and product improvement efforts. It is important to require the continued participation of key suppliers in the overall program planning and Integrated Product Team (IPT) activities so they can understand and contribute to the achievement of the long term program goals. Long-term agreements should be structured with key suppliers who have demonstrated their ability to satisfy program needs. Key suppliers are responsible for the full gamut of post-Engineering and Manufacturing Development (EMD) program activities. During Production, key suppliers should

contribute materially to process control, variability reduction and continuous improvement efforts (see Chapter 9, Section 9.2, Manufacturing Process Control and Continuous Improvement, and Section 9.4, Variability Reduction), cost and schedule requirements, and risk management activities. As part of product improvement efforts (see Chapter 9, Section 9.6, Product Improvement), they should participate in design tasks, trade study responsibilities, risk management responsibilities, and key product and process identification requirements. They should have the flow down authority to assure that their performance allocations are met.

9.3.3 Guidance

To be truly effective in the Production phase and related post-EMD activities, key suppliers should be integrated early into proposal preparation activities and should contribute to Integrated Product and Process Development (IPPD) processes to enable the IPT to take full advantage of their product, system, and process knowledge. Supplier tasks should be fully integrated overall program plans and schedules and a plan should be developed which fully describes the supplier management effort. Successful supplier participation in the IPPD process will require effective communication of the requirements and goals between the prime contractor and supplier. Requirements flow down should be a cooperative effort involving both parties. The prime contractor should have an established system for supplier selection that is based on proven performance on similar programs. Key suppliers should implement the practices described in this Manufacturing Development Guide.

The use of Government Furnished Property, Equipment, Services, and Facilities (GFP) represents a special area of challenge in the management of key suppliers. Effective communications and teamwork between the prime contractor and key GFP suppliers are especially critical. Because of this, government contracts with key GFP suppliers and with the prime contractor must accommodate Associate Contractor Agreements (ACAs) which expedite communications is areas such as interface requirements, changes in design, risks, and schedules. Past Programs have often been hampered by slips in delivery and integration problems when requirements and interfaces have not been effectively communicated to the key GFP supplier. The supplier management plan prepared by the prime contractor should directly address incorporation of key GFP supplier activities and schedules into the overall program plan. If an ACA is implemented it should provide for the participation of the key GFP contractors in the IPT and allow appropriate program management insight into key GFP contractor activities.

9.3.4 Lessons Learned

Programs that have not effectively integrated their key suppliers into their IPTs, along with their plans and schedules, have often had difficulties meeting their requirements. Active supplier participation in the IPT environment, with the corresponding improvement in communication between the prime contractor and the supplier technical communities can greatly reduce the likelihood of material or process changes by the supplier having unanticipated impacts on system integration or performance. The prime contractor’s willingness to commit to long-term relationships can foster greater support for supplier investment in process improvements and cost reduction initiatives.

Historically, past performance data on suppliers has often been lacking or not been as carefully considered as cost in selection process. Supplier performance lead times have often been optimistically factored into program schedules without sufficient accounting for delays. Inadequate supplier risk assessment tools have resulted in little risk identification and little subsequent risk mitigation planning.

9.3.5 Recommended RFP/Proposal Content

9.3.5.1 Government Statement of Objectives (SOO)

See Chapter 9, Section 9.1.1 "Suggested Production Phase Statement of Objectives (SOO) Content."

9.3.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Identification of key suppliers including key suppliers of GFP and integration of supplier activities into the overall program plan.
- Key supplier participation in IPTs.
- Integration of key supplier events/activities into the IMP.
- Identification, analysis, and management of supplier risk.
- Integration of the supplier risk management plan into the overall program risk management plan.

9.3.5.3 Integrated Master Plan (IMP) Content

Topics which the offeror's IMP should cover include the following suggested areas:

- Key suppliers identification and selection, and subcontracts negotiation.
- Key supplier concurrence with requirements allocation and flowdown.
- Key supplier risk assessment and abatement planning and implementation.
- Verification/validation of key supplier process control and VR processes.

9.3.5.4 Contract Data Requirements List (CDRL) Guidance

- Government Furnished Equipment list
- Government Furnished Property list

- Government Furnished Facilities list
- Government Furnished Services list.

9.3.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Integration of key supplier activities, including suppliers of GFP, into the overall program plan, with descriptions of the tasks involved and events (with their exit criteria) to be tracked to assure that supplier activities support overall program performance.
- Supplier capabilities or training in the use of defect prevention processes and techniques such as variability reduction.
- Contractor processes and practices for the management of supplier schedules and for involvement of key suppliers in IPTs.
- Integration of risk management efforts at key suppliers with the program risk effort.
- Flowdown of performance specification and key process characteristics and key product .characteristics.
- Data pertinent to past performance of key suppliers in areas such as product performance, process performance, manufacturing capabilities, customer satisfaction, and schedule adherence.

9.3.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Key Suppliers practices should be based upon:

- The extent to which a disciplined, structured process is used for the integration of key supplier events/activities into the IMP.
- Effective practices for key process characteristics and key product characteristics flowdown to suppliers.
- Evidence of past performance in the management of supplier schedules with emphasis on involvement of key suppliers in IPTs.
- Key supplier experience or training for the use of defect prevention processes and techniques.
- Key supplier past performance in cost, schedule, quality, and customer satisfaction.

- Key supplier risk assessment and risk mitigation planning.

9.4 Variability Reduction

9.4.1 Introduction

Production phase variability reduction (VR) efforts are primarily concerned with maintaining an environment of continuous improvement in product quality and manufacturing process efficiency throughout the production phase. During the production phase, process capability and product quality should continue to improve even after the baseline program requirements have been achieved. Production phase VR tasking falls into three areas: (1) data collection during production operations to monitor process performance and initiate preventive actions; (2) the implementation of process improvements during build activities; and (3) assessment of feedback received from field users and support personnel, and field reliability data.

The VR effort is comprised of tasking that the contractor should identify in the Statement of Work (SOW). No specific deliverable data items need be generated. The results can be reported through normal program status documentation. Figure 9-4 shows the principal Pre-Production MDG practices that will permit the effective implementation of the Variability Reduction practice in the Production phase.

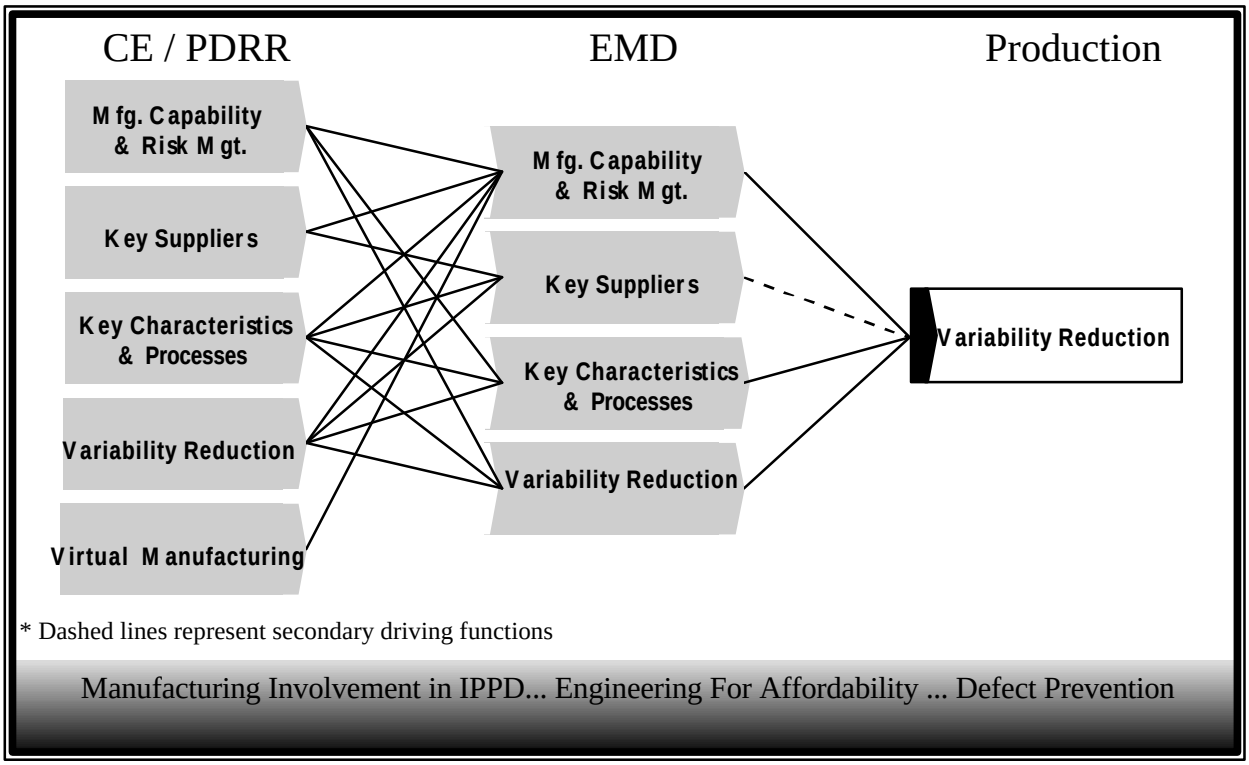


Figure 9-4. How the Variability Reduction Practice Area Integrates with Other Practices

9.4.2 Rationale

VR is a systematic approach to reducing product and process variability in order to improve cost, schedule and technical performance. It introduces the idea that just falling within specification limits (goal posting, pass/fail, attribute testing) is not the best measure of quality. Rather, the variability of a key process and its relationship to process capability becomes a measure of merit. This benefits both the supplier and customer.

For the customer of weapon systems which will be in the inventory for decades, the reduction in parts variability can provide significant paybacks in reducing "infant mortality" problems, improving the performance of components and the overall weapon system, reducing spares and support equipment requirements during field introduction, lowering repair costs, improving durability, and extending overhaul intervals. All of these improvements have a significant impact on reducing operation and support costs as well as improving operational availability and capability. For the supplier, the benefits include improved yields, more reliable scheduling, reduced cycle times, reduced scrap and rework, better cost control, improved competitiveness, and improved customer satisfaction.

9.4.3 Guidance

A notional view of the underlying logic of applying VR for defect prevention in Production is shown in Figure 9-5. The VR effort should start with, but not narrowly focus on, processes

which have been identified as "key processes" (see Chapter 8, Sections 8.7 and 8.8). VR represents a quality philosophy with broad applicability. Fully implemented, it should push down the decision making authority to the lowest levels consistent with the requirement to maintain adequate control of the product. It requires a cross-functional support team, or Integrated Product Team, (IPT) to adequately evaluate potential changes and implement them in an efficient manner. During production start-up, the VR activity can be the means for implementing the risk management plan developed during Engineering and Manufacturing Development (EMD) or for assessing the results of design changes and corrective actions implemented during Low Rate Initial Production (LRIP).

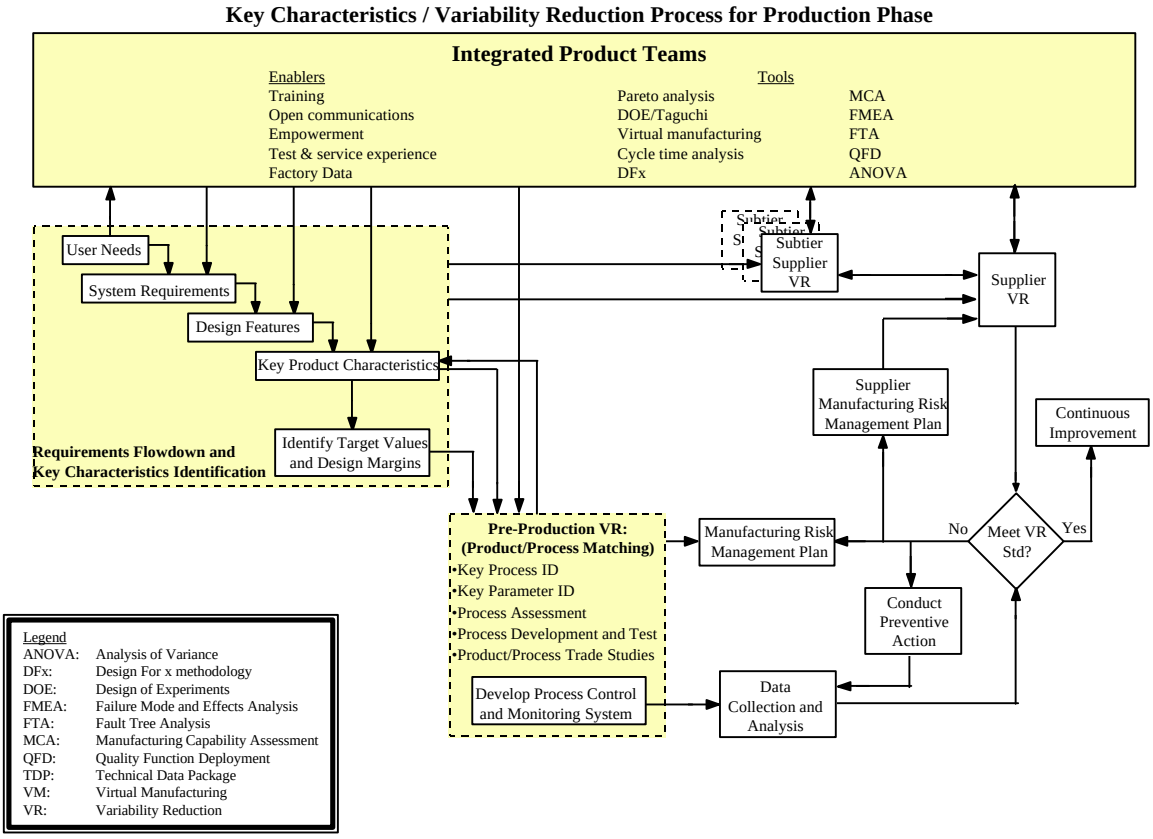


Figure 9-5. Defect Prevention During Production Activities Through Implementation of a Variability Reduction Program.

VR is thus an enabling structure, a well defined process that encourages and empowers the factory workers and the supporting management infrastructure. The techniques associated with process control and on-going evaluations of process capability will identify candidates for process variability reduction. A major requirement for implementing this practice will be maintaining the IPT membership to fully support changes to the product design and/or production processes.

Another major requirement for the effective implementation of Variability Reduction is the flowdown of VR program requirements to key suppliers. Since a majority of the actual

"production" on any system is often accomplished by the prime contractor's suppliers, it is essential that this requirement be effectively flowed to the key suppliers at all levels.

9.4.4 Lessons Learned

Experience has shown that VR represents a significant cultural change over historical practices. It has been successfully implemented at the assembly and subassembly levels through IPTs which were empowered with the authority and responsibility for identifying and correcting product design and process-related problems. These IPTs have included a full range of functional support with the ability to resolve problems, including the preparation of configuration control change proposals.

Ideally, the contractor should have had a VR process in place during the Pre-EMD and EMD phases of the acquisition cycle. If the contractor does not have a VR process in place, introducing the concept as early in the program as possible will provide the maximum cost and schedule benefits. Full implementation of the VR process should be complete by the time Low Rate Initial Production (LRIP) begins in EMD, but implementation of a VR program initiated at any stage of the product procurement cycle, including during production, can be of great value.

It is not necessary for the government to contractually measure the contractor's VR process against a particular standard. Rather it is more important to verify that the contractor has an understanding of the overall intent, and that efficient processes are put in place to achieve the desired end result. This may require streamlining of the Configuration Control process to allow rapid responses, but enough discipline must be maintained to ensure the function and quality of the final product.

9.4.5 Recommended RFP/Proposal Content

9.4.5.1 Government Statement of Objectives (SOO)

See Chapter 9, Section 9.1.1 “Suggested Production Phase Statement of Objectives (SOO) Content.”

9.4.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror’s proposed program:

- Implementation of processes for process control data collection, process control data reduction, evaluation and monitoring of process stability, evaluation and monitoring of process capability, and assessment of potential benefits of process improvements.

- Implementation of VR methods by key suppliers.

9.4.5.3 Integrated Master Plan (IMP) Content

Topics which the offeror’s IMP should cover include the following suggested areas:

- Organizational structure for implementation of VR.
- Change control process.
- Program approach to VR and implementation of LRIP results.

9.4.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this practice.

9.4.5.5 Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following

- Approaches to variability reduction and process control, including the availability of validated process control tools and intended metrics.
- Availability of, or training plan for, personnel at prime contractor's and key supplier's facilities trained in variability reduction and process control techniques.
- Data pertinent to prime contractor and key supplier past performance in variability reduction, and process control, in particular as related to EMD and LRIP results.

9.4.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- Availability of established and validated process control tools and practices and appropriateness of intended metrics.
- Availability of personnel, at prime contractor's and key supplier's facilities, trained in variability reduction and process control techniques, and/or availability of effective training resources.
- Evidence of prime contractor and key supplier past performance in process control and variability management.

9.5 Factory Efficiency

9.5.1 Introduction

In the austere acquisition environment which characterizes today's weapon system development programs, factory efficiency implies the continuous application in the production facility of all appropriate lean manufacturing practices and high performance manufacturing systems. It also implies a dedication to continuous improvement practices and principals during

production. The ultimate objective of factory efficiency is achieving an effective balance between product performance and affordability. Figure 9-6 shows the principal Pre-Production MDG practices that will permit the effective implementation of the Production phase Factory Efficiency practice.

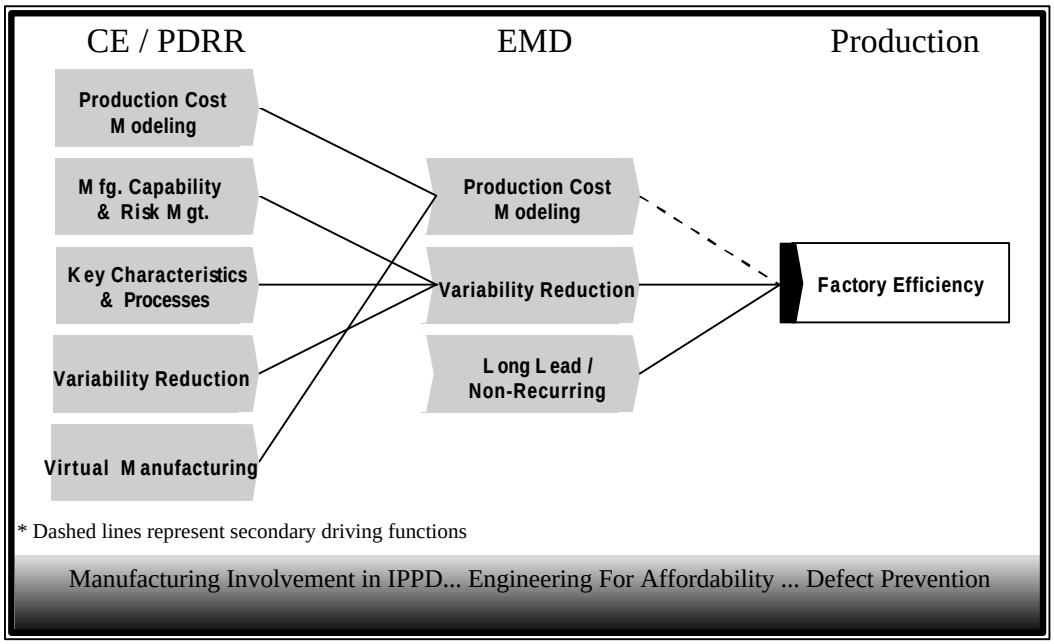


Figure 9-6. How the Factory Efficiency Practice Area Integrates with Other Practices

Many factory efficiency issues extend far beyond the confines of the factory floor. Focusing effectively on risk management and on total program costs, for instance, can lead to evaluations and decision-making which require careful consideration of the industrial base itself, of production capacity issues, and new approaches to make vs. buy decisions. In this environment, the government's Program Office and its manufacturing engineering representative may find themselves at the center of a conflict over immediate economics and long term values. The improvements which are being initiated in the Lean Aircraft Initiative (LAI) will continue to impact production programs for years to come.

9.5.2 Rationale

In the production phases of today's acquisition programs, the role of the government Program Office's manufacturing engineering representative should include a new and determined focus on achieving affordability and best value in production. This requires a much broader perspective than the conventional attention to the contractor's technologies, facilities, and processes. It may include consideration of such issues as overhead absorption, critical mass, industrial base sustainment, capacity constraints, and support capabilities. The Program Office's manufacturing engineering representative may thus be required to participate with the contractor in the use of

such tools as cost modeling and discrete event simulations in order to analyze the risks and benefits associated with these overarching production issues.

9.5.3 Guidance

Consistent with the spirit of continuous improvement, the role of the Program Office's manufacturing engineering representative should encompass proactive support of improvements which may be realized by changes in the government's processes, schedules, and requirements as well as internal improvements in the contractor's manufacturing methods and processes. New kinds of financial incentives, for instance, may be required. The effective optimization of many of the key elements which characterize the high performance manufacturing organization may require adjustments on the part of the government and the contractor team. Among them:

- continuous process flow
- Single Process Initiatives (SPIs)
- just-in-time manufacturing and inventory systems
- *Kanban* card inventory pull systems
- empowered employee teams
- business unit production cells
- process-based or activity-based cost management.

The production contract should provide Program Office insight into the contractor's manufacturing management processes. The IPT which has functioned throughout the development process continues through the production phase with significant changes in membership, and with the IPT manufacturing engineering function moving from a participatory role to a leadership role. The contract should be tailored so as to continue the Program Office's role in monitoring best value evaluations and make vs. buy decisions, and to encourage the use of cost modeling and capacity analyses.

The role of the government's manufacturing engineering function is to represent the customer's interests in effective risk mitigation for cost, schedule, and quality--and to maintain a sensitivity to larger considerations such as industrial base issues and capacity constraints. This role includes the analysis of economic data to support contractor decisions aimed at optimizing the acquisition process over a total product life cycle rather than for the immediate contract alone.

9.5.4 Lessons Learned

The Lean Aircraft Initiative and other initiatives promoting factory efficiency grew out of the move to global competition in the defense acquisition process. With a de-emphasis of the requirement for continental U.S. sources for everything, and with the rise of high performance products in other countries, the need to implement lean practices became a survival issue. Defense

contractors at all levels of the supply chain are embracing the lean principles and building on lessons learned in the U.S. auto industry and in other commercial competition sectors.

9.5.5 Recommended RFP/Proposal Content

9.5.5.1 Government Statement of Objectives (SOO)

See Chapter 9, Section 9.1.1 "Suggested Production Phase Statement of Objectives (SOO) Content."

9.5.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror's proposed program:

- Factory efficiency initiatives which will be used to achieve the proposed Average Unit Production Price (AUPP).
- Continuous production improvement practices which will be used during the production phases.

9.5.5.3 Integrated Master Plan (IMP) Content

Topics which the offeror's IMP should cover include the following suggested areas:

- Program Office insight for make vs. buy procedures.
- LAI implementation.
- Continuous improvement process documentation.
- Total acquisition costs in economic analysis.
- Use of cost models in economic decisions.
- Management of cost, schedule, and quality risk in the production environment.

9.5.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

9.5.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Demonstration of an ongoing production phase commitment to affordability, and a sensitivity to total acquisition costs, capacity constraints, and industrial base issues.

- Sustainment during the production phase of the open environment created by the IPT processes in the preceding phases of the program.

- Direct participation of manufacturing engineering in the decision processes associated with quality metrics, economic trade studies, and make vs. buy decisions.

- Functioning of the Program Office's manufacturing engineering representative as a member of the IPT, communicating directly with the Program Office with respect to opportunities to improve factory efficiency, contract effectiveness, requirements modifications, schedule changes, and other areas.

9.5.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of the contractor's capabilities in the area of factory efficiency and lean manufacturing should be based on:

- Continued reduction of the AUPP for each procurement.

- Effective contractor and Program Office monitoring of changes to the product and the production processes to ensure that product performance is not sacrificed in the continuing effort to improve factory efficiency, or vice versa.

- Maintenance of the basic disciplines of change management, revalidation and reverification of key characteristics, and the protection of essential functions in the infrastructure.

9.6 Product Improvement

9.6.1 Introduction

Product improvement is a practice used throughout the defense industry which has gained new emphasis in the era of reduced budgets and acquisition reform. Product improvements are changes made in the production phase to address new performance requirements and/or to take advantage of new technologies or subsystems which enhance performance or lower cost. Figure 9-7 shows the principal Pre-Production MDG practices that will permit the effective implementation of the Production phase Product Improvement practice.

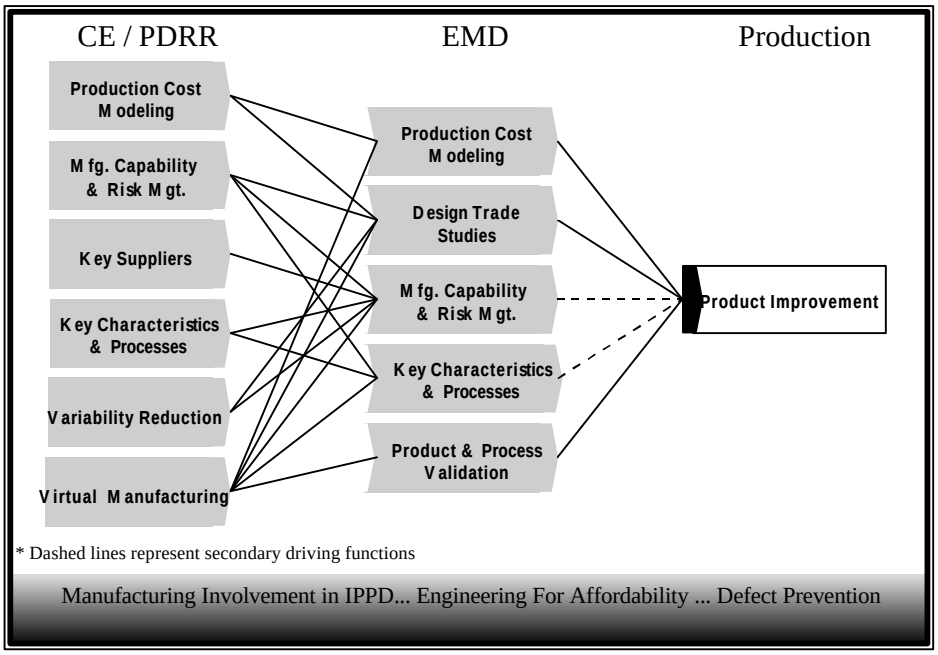


Figure 9-7. How the Product Improvement Practice Area Integrates with Other Practices

Performance based specifications have changed the processes for product improvement, giving the contractor greater flexibility to make changes which improve or do not adversely affect performance (provided that the design and performance implications are validated and verified as part of the change process). Product improvements which affect form, fit or function and therefore impact interchangeability, spares, or other areas call for program-level approvals prior to proceeding.

The use of block contract changes and single process initiatives (SPIs) provides for controlled, efficient, and cost effective introduction of changes. Significant administrative costs are avoided when a product design improvement is implemented simultaneously on multiple contracts via the block contract change process. Further, if manufacturing implementation of the product improvement requires a change to a process used on programs throughout a contractor's business base, then a related SPI generates still more cost avoidance by precluding the need for multiple processes to satisfy the same product requirement.

9.6.2 Rationale

Product improvement during the production phase of a program is the result of the need to meet new performance requirements, correct design deficiencies, improve product yield for cost, schedule and quality reasons, or to take advantage of new product or process technologies. With performance based specifications, contractors have more authority to incorporate changes. The manufacturing engineer's role is to assess the projected impact of such changes on the manufacturing process and plan the incorporation of the change in the factory.

9.6.3 Guidance

During the Production phase of an acquisition program, manufacturing engineering's function in the IPT is more essential than in earlier phases. Government Program Office manufacturing engineers need insight into the contractor's product improvement plans in order to monitor the risk and cost issues associated with their implementation. Changes which do not affect the product design may still have a great impact on manufacturing tools and processes. The Program Office manufacturing engineer's role is to maintain insight into those changes that impact the manufacturing processes and/or the maintenance and repair of deployed units at operating bases and military depots. The Program Office manufacturing engineer also maintains insight into the production cost model (PCM).

9.6.4 Lessons Learned

Contractors have often introduced product changes to improve fit and function based on quality data gained through the process of maintaining a continuous learning curve reduction over time. The customer often adds new requirements based on new threats or lessons learned in the deployment of the product. Historically, these changes result in increased costs. Without a block change process, changes are often incorporated in a manner that can add to unit cost as well as to life cycle costs for support. Programs have often experienced obsolete spares inventories and expensive changes to support equipment due to loosely managed product improvements, for instance. Cost growth is often associated with added performance requirements.

9.6.5 Recommended RFP/Proposal Content

9.6.5.1 Government Statement of Objectives (SOO)

See Chapter 9, Section 9.1.1 "Suggested Production Phase Statement of Objectives (SOO) Content."

9.6.5.2 Contractor Statement of Work (SOW)

All offerors are encouraged to discuss the topics listed below in submitted SOWs, to the extent that they are applicable to the offeror’s proposed program:

- IPT control of the configuration change control process.
- Manufacturing Engineering insight into Production Cost Model impact.
- ST/STE/SE considerations as addressed in the change process.

9.6.5.3 Integrated Master Plan (IMP) Content

Topics which the offeror’s IMP should cover include the following suggested areas:

- Production phase support for timely delivery of the product.

- Block change planning in the IMS to assure that everyone understands and supports the schedule for incorporating changes.
- Changes which impact ST/STE/SE.
- In the PCM, product improvements are incorporated as block changes and non-recurring costs are identified.

9.6.5.4 Contract Data Requirements List (CDRL) Guidance

No formal CDRLs are suggested for this section.

9.6.5.5 Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for managing and controlling design, product, and process configuration .
- A block change plan.
- The Production Cost Modeling process.
- Prior experience in managing product improvement initiatives in production programs.
- Applicable key supplier processes for managing and controlling design, product, and process configuration.

9.6.5.6 Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage product improvement processes should be based upon:

- An established and effective configuration management process as it relates to product improvements.
- A documented Block Change Plan.
- A Production Cost Model developed in EMD and maintained for production.
- The past performance of the prime contractor and key suppliers in initiating and managing product improvements, including related configuration and cost management requirements.

APPENDIX I

I. MDG ACRONYMS

ACA	Associate Contractor Agreement
ANOVA	Analysis of variance
ANSI	American National Standards Institute
AUPP	Average Unit Production Price
CAD	Computer Aided Design
CAIV	Cost as an Independent Variable
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CE	Concept Exploration
CFP	Contractor Furnished Property
CI	Complex Item, as in a design specification
CO	Contracting Officer
CONUS	Continental United States
COTS	Commercial Off-the-Shelf
CPARS	Contractor Performance Analysis Review System
Cpk	Capability Index
CRAD	Contractor Research and Development
DAL	Data Accession List
DFx	Design for “x”
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DoDR	Department of Defense Regulation

DOE	Design of Experiments
DRFP	Draft Request for Proposal
DTC	Design to Cost
DUE	Data Update Events
EA	Environmental Assessment
EDI	Electronic data Interchange
EMD	Engineering and Manufacturing Development
EPA	Environmental Protection Agency
FMEA	Failure Mode & Effects Analysis
FTA	Fault Tree Analysis
GFE	Government Furnished Equipment
GFP	Government Furnished Property
ICD	Interface Control Document
IMP	Integrated Master Plan
IPPD	Integrated Product and Process Development
IPT	Integrated Product Teams
IRAD	Internal Research and Development
JACG	Joint Aeronautical Commanders Group
LAI	Lean Aircraft Initiative
LCC	Life Cycle Cost
LCCM	Life Cycle Cost Model
LRIP	Low Rate Initial Production
LRU	Line Replaceable Unit
MCA	Manufacturing Capability Assessment

MCRA	Manufacturing Capability Requirements Analysis
Mfg.	Manufacturing
MDG	Manufacturing Development Guide
MM/PCR	Manufacturing Management/Production Capability Review
MRP	Materials Requirement Planning
MRP II	Manufacturing Resource Planning
NDI	Non-developmental item(s)
NDI	Non-destructive Inspection
NGS-IPT	Non-Government Standards - Integrated Product Team
OSHA	Occupational Safety and Health Agency
PAC	Product Acceptance Criteria
PBBD	Performance Based Business Description
PBBE	Performance Based Business Environment(s)
PCM	Production Cost Model
PCR	Production Cost Requirement
PDR	Preliminary Design Review
PDRR	Program Definition and Risk Reduction
PIO	Proposal Instructions to Offerors (Section L)
PMR	Program Management Review
Pre-EMD	Pre-Engineering and Manufacturing Development
QFD	Quality Function Deployment
RAA	Required Assets Availability
RFP	Request for Proposal
ROM	Rough Order of Magnitude

SE	Support Equipment
SEMS	Systems Engineering Master Schedule
SOO	Statement of Objectives
SOW	Statement of Work
SPC	Statistical Process Control
SPO	System Program Office
SPI	Single Process Initiatives
SRA	Schedule Risk Assessment
SRD	System Requirements Document
SRU	Shop Replaceable Unit
SSAC	Source Selection Advisory Council
SSEB	Source Selection Evaluation Board
ST/STE	Special Tooling/Special Test Equipment
SVR	System Verification Review
T1	first unit
TBD	To Be Determined
TDP	Technical Data Package
TIM	Technical Interchange Meeting
TQM	Total Quality Management
VM	Virtual Manufacturing

II. *Engineering and Manufacturing Practices For Defect Prevention: A Guide For Aerospace Acquisition Management Teams, Section 4*

4. DISCUSSION

This section is intended to assist the reader in understanding why defect prevention practices are important from the standpoint of affordability and in mitigating the risks of transitioning to production. It serves as a primer by introducing and summarizing some of the process attributes, tools, and business practices that may be applied to complex aerospace acquisition programs. Given that equipment acquired by aerospace community buying activities includes everything from satellites and manned and unmanned vehicles to engines, avionics and ground support equipment, it should be obvious that there is no "one-size-fits-all" approach to defect prevention. In addition, the summaries of tools, attributes and business practices contained herein do not provide sufficient detail to be the sole reference source for the uninformed reader. Users of this guide are strongly urged to gain a detailed understanding of these topics, as well as other related engineering and management practices and philosophies, prior to applying any of the principles contained herein.

4.1 SCOPE OF THIS GUIDE

Aerospace community acquisition management teams can consult this guide in the planning process for nearly any development or production contract. The guide's applicability, however, may vary depending on the program and acquisition process (particularly for acquisitions of Non-Developmental Items, Commercial Off-the-Shelf systems, purely build-to-print acquisitions such as reprocurements of spares and repair parts, and programs where only software or services (such as maintenance) are being procured).

4.2 DEFECT PREVENTION - A DESCRIPTION

A defect prevention approach emphasizes matching the design requirements to the process limitations and then controlling the process to facilitate the production of conforming product. The additional confidence in design and production planning reduces development phase uncertainty in cost estimating and in cost-containment efforts, decreasing overall program risks. It is therefore increasingly relevant to consider defect prevention approaches proposed by offerors as important discriminators in source selection.

Reduced costs and risk can be achieved through explicitly influencing the design process with producibility and manufacturing considerations. Doing so improves product quality and manufacturing efficiency by enhancing the predictability of manufacturing operations, reducing waste in material and labor, decreasing production cycle time, reducing the need for engineering changes, and minimizing the required overhead and sustaining engineering.

4.2.1 Integrated Product and Process Development (IPPD) Framework

Since defect prevention encompasses both design and manufacturing, it is initially applied during the development phase, normally within an integrated product and process development framework. IPPD focuses on achieving robust, producible and supportable designs.. Within this

framework, producibility objectives are achieved in a systems engineering environment utilizing a thorough knowledge of manufacturing process risks. While this early emphasis on the optimization of the design/manufacturing process interface may necessitate the application of additional resources in the development phases, the potential benefits (including decreased engineering changes, production cycle time, rework, and inspections) translate into improved life cycle affordability and reduced production transition risk.

IPPD requires the involvement of personnel from a number of functional disciplines (e.g., design, manufacturing engineering, production operations, quality, tooling design and fabrication, industrial engineering), including appropriate subcontractor personnel, in the design process. In an IPPD approach, design trade studies will explicitly consider manufacturing factors (e.g., manufacturing technology, tooling, fabrication and assembly costs, sources of supply, tolerances, part count, yields and verification methods) to ensure that fully informed decisions affecting these factors are made before significant resources are committed.

There are many tools for facilitating IPPD. As an example, quality function deployment (QFD) provides a structured, team-oriented planning methodology for translating the top-level customer needs into appropriate requirements at each level of product and process design. The proper application of QFD has been proven to (1) reduce overall development time, (2) reduce the number of changes required after production start, and (3) improve customer response to new products. A subset of tools for IPPD, focusing on defect prevention, are given below.

4.2.2 Tools and Attributes

4.2.2.1 Identification and Control of Key Product Characteristics

Key product characteristics are the features of a material or part whose variation has a significant influence on product fit, performance, service life, or manufacturability. The designation of key product characteristics is a valuable method for design engineers to communicate to manufacturing personnel the specific features of the design that are most important for the factory to control during manufacture and test. The designation of key product characteristics also indicates to other engineers those product features that need special care when design changes are being made and can be used by manufacturing personnel to identify design features that factory data indicate are problematic. In any case, the principal benefit of identifying key product characteristics is that doing so highlights those manufacturing processes -- out of the thousands that can exist in a large factory -- which should be the focus of process control and variability reduction efforts.

World class manufacturers identify each part's key product characteristics on the part's drawing and on affected assembly drawings, work instructions and process specifications. Because the continuous reduction in part-to-part variation in these key product characteristics is of primary importance, statistical process control techniques are used for controlling key product characteristics in production.

A key characteristic must be measurable using either variable (i.e., discrete dimensions) or attribute (i.e., go/no-go) data. Key product characteristics should be defined in terms of impact

upon both the external and internal customers. If, for example, a characteristic results in a high internal rejection rate for the manufacturer, that characteristic should probably be considered key. Viewed from the ultimate (external) customer's perspective, such a characteristic may not appear important; however, it is important from the internal customer's perspective because it results in rework, scrap and lost dollars.

A number of methodologies exist to facilitate the identification of key product characteristics, including analysis of historical data, Failure Modes and Effects Criticality Analysis (FMECA), and Fault Tree Analysis (the latter two methods should be applied to identification of characteristics/parameters associated with both the product and process design). QFD (see above under IPPD discussion) and design of experiments can also be employed to assist in the identification of key product characteristics.

Key process parameters derive directly from the key product characteristics. As manufacturing processes are designed in conjunction with design of the product, the processes that produce the key product characteristics are identified. The individual key process parameters are then identified using QFD or a similar approach so that appropriate controls and variability reduction practices (see below) can be developed and employed to ensure the final key product characteristics will conform. Once these key product characteristics and associated key process parameters are identified, process capability studies are used to verify that they can be achieved with the planned tooling and processes, or the parts or processes are redesigned as required.

Note: It is important for the purposes of this guide to distinguish between “key product characteristics” and “key processes” as defined herein and the commonly used term “critical characteristic”. In general, key product characteristics and key processes are associated directly with product fit, performance, service life, or manufacturability, whereas critical characteristics focus on personnel safety and mission performance. A critical characteristic is any feature of an end item, subassembly, material, or process for which a resulting nonconformance is likely to result in a hazardous or unsafe condition for individuals using, maintaining, or depending on same. Nonconformance in a critical characteristic can also be considered likely to prevent performance of the tactical function of a major end item such as an aircraft or weapon system.

4.2.2.2 Design to Manufacturing Process Capability

All manufacturing processes exhibit variability. For processes in a state of statistical control, this variability can generally be characterized as a normal distribution (measured in standard deviations or “sigma”) about a mean value. Design tolerances are established so that manufacturing process variability falls within these limits. This relationship is measured by process capability indices (Cp, Cpk). Commonly, the manufacturing processes that control key product characteristics must achieve a certain minimum process capability index value. (This value typically ranges from a Cpk of 1.33 for non-complex mechanical parts to 2.00 for parts used in complex commercial electronic systems that must exhibit extremely high reliability.)

In order to design a product to the capability of the manufacturing process that will produce it, it is imperative that that capability be understood. Depending on whether the manufacturing process is presently in use or must be developed, the process capability analysis will require using

either existing historical data, designed experiments, or some method of modeling or estimating process capability. What needs to be determined is the natural variability of the process when in control (stable). Basic statistical techniques can be employed in this analysis, including tests for normality, to characterize the process and determine whether it is, in fact, under control. If not, causes of special variation are identified and eliminated.

World-class manufacturers use their knowledge of process capabilities to analyze tolerance stacking in every assembly interface area. By assessing the capability of each fabrication process and of assembly tooling, and by understanding the statistical tolerance range of each part type, the impact of worst case tolerance stackups can be assessed. Doing so allows an early influence on the design of parts, processes, and tooling that can preclude unacceptable tolerance stackups.

Prior to the initiation of production, world-class manufacturers validate and verify (i.e., "proof") that all key processes demonstrate sufficient process capability to ensure that the key product characteristics for parts resulting from the process will be within the design tolerance. Validation and verification is performed in a production-representative environment, including production workers, tools, space, materials, documentation, etc. and is scheduled so that required corrective actions (such as process or tooling changes) can be accommodated, if test results dictate, in time to affect the fabrication and assembly of the first production articles.

4.2.2.3 Design for Assembly/Manufacturing (DFA/M)

DFA/M techniques enable the reduction of product cost through design simplification. DFA/M achieves such simplification through parts reduction and by ensuring that the remaining parts are easy to manufacture and assemble. DFA/M usually results in significantly enhanced product quality because many nonconformances are attributable to product complexity. Defects such as missing or loose fasteners, faulty connections, and incorrectly installed parts all tend to be a function of product complexity. For each fastener or connector eliminated from the design, for example, the opportunity for one of these types of defects to occur is also eliminated. (Source: "Product Design for Assembly," Boothroyd Dewhurst, Inc., 1991)

4.2.2.4 "Robust" Design

A "robust" design results in a product that is insensitive to or tolerant of sources of variation and change that are difficult, costly or impossible to control. These sources (sometimes referred to as "noise") may include such factors as environmental conditions within a factory, minor variations in raw material, or differences in how individual customers use the product. Robust designs perform as intended despite these noise factors.

A commonly used method to achieve robustness is "parameter design," in which the optimum parameters of key product and process characteristics (e.g., material composition, processing time, pressure, etc.) are determined such that the product is least sensitive to "noise" factors. The selection of these parameters and their settings is accomplished using statistically designed experiments, among which Taguchi fractional factorial experiments are perhaps the best known. Experience indicates that application of these techniques results in products of superior quality, while achieving significant cost reductions.

4.2.2.5 Geometric Dimensioning and Tolerancing (GD&T)

GD&T is a methodology applied to the preparation of engineering drawings or other media to more clearly describe design intent. It provides the dimensions of a component and its tolerances in a way that eliminates confusing and inconsistent notes, implied datums and incomplete specifications. One of the primary benefits of this technique is that it resolves the common engineering drawing deficiency of not identifying datum reference points from which repeatable measurements can be made. The identification of such reference points is critical to the assembly process and to understanding the impact of variation of individual components in the assembly. Despite its obvious advantages over other methods, GD&T is still not universally applied across the aerospace industrial base, hence its inclusion in this guide. The ANSI standard, Y14.5M-1982, provides instruction and ground rules for proper application of this technique. (Source: "Defect Prevention," Appendix II, Victor E. Kane, 1989).

4.2.2.6 Process Variability Reduction (PVR)

Every production process results in some variation in the product characteristics it generates. The product characteristics may be in terms of physical, material, or chemical properties. In general terms, the product's characteristics represent output variables of the process. Input variables are factors such as: the quality of materials used; the condition of the equipment; the training and skill of the operator; the values of nominal control settings; and the adequacy of fixtures or jigs that support and position materials. For a stable production process, the output variability is generally seen as a normal distribution about some average value. The average value may also vary with time, but in a stable process, this variation is relatively small. In the broadest sense, process control constitutes the quality assurance provisions for ensuring delivered products meet all requirements. For stable, capable processes, this generally translates to ensuring that all input variables are properly controlled with some form of feedback from output variables.

Reducing variability in key product characteristics, by definition, always results in a relative benefit. The Taguchi Loss Function applies to such characteristics, showing the closer to the nominal, or target, value the characteristic is, the more reliable the product will be. PVR is a systematic approach for continuously seeking sources of variation within the key product characteristics and process parameters that control those characteristics and then developing means for eliminating the sources. Such means can include additional design improvements that would increase design robustness, eventually eliminating the applicable characteristics from the list of those considered key. After the key product characteristics have been identified, along with the key manufacturing process parameters that control them, basic statistical process control techniques can be used to ensure the processes are capable and stable (e.g., X bar/R charts).

Tools that can be used to seek out sources of variation in processes include the following.[1] :

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[1] This discussion regards improvements to stable, capable processes that aren't producing any nonconforming product. Nonconformances result from processes that are out of control and/or incapable and need to be handled with a closed loop corrective action system that identifies and eliminates their root causes.

a. Process flow charts can show the complexities within a process and interrelationships among process steps. Experience indicates that the excessive or redundant handling or movement of product, and the inefficient sequencing of process steps can be eliminated or reduced through use of process flow charts.

b. Pareto charts can help prioritize improvement opportunities identified using a variety of analytical techniques.

c. Cause and effect (Ishikawa) diagrams can also be used to help show interrelationships and prioritize improvement activities.

d. Design of Experiments (DOE) analytical techniques can eliminate or control sources of variation by identifying and addressing the most influential sub-process sources of variation.

e. The Poka-Yoke or fail-safing technique involves implementation of hardware, software or monitoring instrumentation sufficient to "lock-out" or eliminate process failure modes. This approach is a fundamental defect prevention tool intended to preclude the possibility of process errors that could result in product defects.

4.2.2.7 Control of variation in the measurement system Measurement processes exhibit variation just as manufacturing processes do. For this reason, it is important that measurement equipment repeatability and reproducibility studies be conducted when performing process capability studies to ensure variation in the measurement devices variation is not consuming an excessive amount of the design tolerance. Such studies of the capability and natural variation inherent within measurement equipment are often called gage variation, or repeatability and reproducibility (Gage R&R) studies. They differ from the traditional calibration/metrology programs essentially in the details of the information obtained about the gage's accuracy, capability and reliability. Inherent variation within the gage is known as repeatability and can be measured by having one operator take repeated measurements of one characteristic on one part. Reproducibility takes into account differences between operators. Results of Gage R&R Studies are made statistically valid by controlling possibly superfluous sources of variation and in the number of trials used to obtain data. They are expressed in statistical terms and related to particular part characteristics by determining how much engineering tolerance for the characteristic is taken up by inherent gage variation.

4.2.2.8 Root cause, closed loop corrective action

Because even defect prevention will never be 100% effective in eliminating the production of defective product, some form of the material review and corrective action system used in basic quality systems is still required. However, basic quality systems have tended to place the greatest emphasis on the disposition of defective material (i.e., determining whether it should be used as is, repaired or reworked, or scrapped), and relatively little emphasis on correcting the cause of the defect. In contrast, defect prevention emphasizes prevention of the defect's recurrence, whether the deficiency was found in incoming, in-process, or completed parts and assemblies. Corrective action normally involves the use of multi-functional teams and formal problem solving techniques,

combined with high-level management attention and tracking. This results in evaluation and implementation of changes in designs, manufacturing processes, tooling, work instructions, training, etc., to ensure the problem does not recur.

4.2.2.9 Continuous Improvement (CI)

The basic objective of CI is to constantly reduce the cost to deliver a product of increasing quality. This is achieved by assessing the root causes of both process and product variability and reducing or eliminating their influence through the institution of cost-effective changes.

Process CI: For production processes, CI initiatives may include such things as additional operator training, more frequent equipment maintenance, and refinement of control settings or improvements to fixtures. CI should also be applied to other business/management processes which, if not reliable and repeatable, may increase variability. For example, while production/manufacturing variability may be under control and constantly being reduced, out-going product quality may be compromised by ineffective quality assurance, document control, or configuration management systems. It is important that CI be focused on production, business and management processes throughout the lifecycle to ensure a cost-effective, quality product.

A tool that many companies have found useful for implementing continuous process improvement is Kaizen. This Japanese word means gradual, unending improvement. It is the systematic foundation of an organizational culture whereby all members of the organization are constantly seeking ways to perform tasks more efficiently and effectively. Kaizen results in everyone doing little things better and setting/achieving higher and higher standards. While small, individual changes may not appear to mean much, the many gradual changes that result when a company implements Kaizen often add up to significant measurable improvement over time. Kaizen implementation also often results in large, immediate improvements as the need for changes in factory layouts, product flow, etc., are discovered and implemented.

Product CI: Another aspect of CI is the evaluation of the design to determine if there are cost-effective ways to make it more robust (more tolerant to variation). As discussed earlier, design robustness can be improved through redesign, resulting in a reduction of key product characteristics. As part of such an effort, designers would consider how variability associated with the factory infrastructure (inventory control, material handling, etc.) would affect the variability of product components, subassemblies, assemblies and related manufacturing/fabrication processes. The designers would then take actions to reduce such product variability through design modifications and, to the extent that robust design solutions are not cost-effective, recommend process improvements for mitigating the effects of the variability.

To facilitate CI, world-class manufacturers employ systems to collect and analyze process and product metrics which provide insight into product quality, delivery, performance, cost, and manufacturing efficiency. These systems use the data collected to measure effectiveness of CI initiatives as well as to identify areas for additional investigation and corrective action. These systems also can alert the supplier or customer to anticipated contract delivery schedule delinquencies, production difficulties, or delays.

III. CONSOLIDATED MDG SECTIONS L AND M CONTENT

CHAPTER 4. MANUFACTURING ENGINEERING'S ROLE IN IPPD

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- The IPPD processes which the offeror proposes to employ.
- The proposed approach to populating multi-functional teams and ensuring participation by suppliers and/or customers.
- A description of previous experience with IPPD processes (including performance metrics and demonstrated cost and schedule benefits).
- Plans to introduce and institutionalize the IPPD process in the offeror's organization (if the offeror has no previous IPPD experience).
- A description of the methodology used by the IPT for validating process cost and capability data to support IPPT trade decisions.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- An established or proposed IPPD process, including team member roles and responsibilities.
- Previous experience which demonstrates cost and schedule benefits realized by IPPD processes.
- Presentation of a viable plan which can reasonably be expected to effectively institutionalize IPPD in the offeror's organization (if the offeror has no previous IPPD experience).
- Data on existing process cost and capabilities and evidence that the data has been used in design trade studies.
- An established, or proposed, demonstration or analytical approach to validate that the process capabilities needed to achieve the stated affordability requirements are within industry standards or identified as cost and schedule risk issues.

CHAPTER 5. ENGINEERING FOR AFFORDABILITY

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for cost requirements allocation and flowdown.
- Documentation practices for cost requirements allocation and flowdown.
- Description of formal programs/tools/techniques to be used in engineering for affordability to maximize cost avoidance in manufacturing and sustainment.
- Methods for including cost considerations in design trade studies.
- Description of requirement cost partitioning processes.
- Description of cost risk identification/mitigation processes.
- Description of contractor's past performance in cost requirements management under the IPT concept.
- Flowdown of engineering for affordability tools, techniques, and practices, along with related training, to appropriate suppliers.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Engineering for Affordability practices should be based upon:

- Established practices for cost requirement allocation and flowdown.
- Planned implementation of resources and tools for the consideration of cost requirements in the design trade studies.
- Planned use of formal cost avoidance initiatives/programs such as those described above.
- Planned use of cost risk identification/mitigation processes.
- Past performance of prime contractor and key suppliers in establishing and meeting cost allocations.
- Plans for flowing down to appropriate suppliers cost avoidance initiatives/programs such as those described above.

CHAPTER 6. QUALITY SYSTEMS

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- The offeror's quality systems should be described in the proposal to confirm that a formal, systematic approach is in place to assure product quality.
- The offeror's proposal should address the processes and procedures which will enable the manufacturing engineering and quality engineering functions to participate fully in the IPT.
- The test and evaluation program should reflect the incremental verification of objectives throughout the design cycle.
- The offeror should provide for government insight into the quality program and should flow down this insight process to suppliers.
- The proposal should reflect the offeror's plans for using commercial or industrial standards in place of government specifications, and the strategy for implementing these standards with suppliers.
- The offeror should incorporate the proposed defect prevention tools into the final contract.

Evaluation Criteria Guidance (Section M)

The Quality System proposed by the offeror will be evaluated on the extent to which it provides assurance of the offeror's ability to prevent the production of defective products. Proposed systems should provide for:

- Ensuring effective management of identified risks.
- Integration of technical and management processes and systems.
- Measurement of the effectiveness of processes and systems.
- Continuous improvement of processes and systems.
- Training personnel in the use and deployment of defect prevention tools and techniques.

CHAPTER 7. PRE-EMD PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

7.2 Production Cost Modeling

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for development and validation of the Production Cost Model.
- Processes for development and validation of production cost estimates.
- Data pertaining to use and performance of PCM on previous programs.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Production Cost Modeling practices should be based upon:

- Demonstrated processes for development and accuracy of cost models.
- Demonstrated processes for development and validation of production cost estimates.
- Experience on previous programs related to use and performance of PCM.

CHAPTER 7. PRE-EMD PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

7.3 Manufacturing Capability Assessment and Risk Management

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following::

- Identification of new and environmentally questionable materials and processes.
- Environmental-related manufacturing risk factors incorporated into risk management planning.
- Identification of related issues outside the scope of this program, including funding sources such as IRAD, CRAD, and related contracts.
- Industrial capacity and industrial base sustainment issues.
- IMP reflection of risk management activities.
- IMS reflection of cost and schedule risk management activities associated with the time-phasing and stability of funding from other sources.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to manage risk and assess manufacturing capabilities should be based upon:

- Identification of the databases and processes employed to assess the potential risk of qualifying new materials and proving immature processes.
- Proposed plans for addressing industrial capacity and industrial base sustainment issues.
- Reflection in the program schedule of areas of risk resulting from planned funding sources outside the immediate contract.

CHAPTER 7. PRE-EMD PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

7.4 Key Suppliers

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Approach to identification of key suppliers, including key supplies of GFP, along with criteria used to make the determination.
- Approach to integration of key supplieractivities into the overall program plan, including descriptions of the tasks involved, and events, with exit criteria, to be tracked to assure that supplier activities support overall program performance.
- Performance specification, key process, characteristics and key product characteristics flowdown.
- Past performance data relative to management of key supplier schedules and involvement of key suppliers in IPT activities
- Data pertinent to key supplier past performance in areas such as manufacturing capabilities, use of defect prevention techniques, customer satisfaction, and schedule adherence.
- Data to be collected and analyzed on the present program.
- Approach to integrating the risk management effort for key suppliers with the program risk management effort.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- Defined criteria for the identification of those suppliers who are key.
- Disciplined, structured processes used for the integration of key supplier events/activities into the IMP and for requirements flowdown.
- Effective performance specification, key process characteristics and key product characteristics flowdown processes.
- Evidence of past performance in the management of supplier schedules and the involvement of key suppliers in IPTs.
- Key supplier experience in (or training plan for) the use of defect prevention processes and techniques.
- Key supplier past performance in cost, schedule, quality, and customer satisfaction areas.
- Data collection and analysis planning.
- Key supplier risk assessment and risk abatement plans.

CHAPTER 7. PRE-EMD PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

7.5 Key Characteristics and Processes

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Description of a design system process which identifies key product characteristics, key production processes, balances key product design requirements with the capability to manufacture the product, identifies proposed verification methods, and flows down key characteristics to key suppliers.
- Data pertinent to prime contractor and key supplier past performance in key product characteristics and key process identification.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- The extent to which a disciplined, structured, and demonstrated process is used for requirements identification and allocation, identification of key product characteristics and key process parameters, and the achieving of balance between product design requirements and process capabilities.
- Evidence of prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

CHAPTER 7. PRE-EMD PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

7.6 Variability Reduction

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the goals of this practice will be achieved, including the following:

- A description of the planned approach to variability reduction.
- Availability and planned utilization of defect prevention techniques and process control tools for controlling processes and assuring product quality.
- Metrics used to manage processes.
- Data on prime contractor and key supplier past performance in variability reduction, process control, and product / process matching.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ variability reduction processes should be based upon:

- The merit of the planned approach to variability reduction.
- The planned utilization of defect prevention techniques and availability of established and validated process control tools and practices.
- The robustness of the planned metrics for managing processes.
- Evidence of prime contractor and key supplier past performance in variability reduction, process control, and product / process matching.

CHAPTER 7. PRE-EMD PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

7.7 Virtual Manufacturing

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how achievement of the goals of this practice will be ensured, including the following:

- Virtual manufacturing, prototyping, and planning processes to be used in the pre-EMD program phase to ensure the effective early involvement of manufacturing engineering in the IPT design effort.
- Early involvement of virtual manufacturing tools to provide input to production planning and to production risk identification and management.
- Resources and experience needed to execute virtual manufacturing applications for the transition of the concept design into EMD and Production.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ virtual manufacturing processes should be based upon:

- Demonstrated ability to manage risk through assembly simulation, process flow simulation, and process capability analysis.
- Demonstrated ability to evaluate manufacturing resource requirements and provide schedule credibility through process flow simulation.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.2 Production Cost Modeling

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Established processes and procedures for developing and validating a PCM.
- Documentation and maintenance practices for control of the PCM configuration.
- The contractor's preliminary model for evaluation, if available.
- Data pertinent to prime contractor and key supplier past performance in developing and maintaining realistic PCMs or similar models.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror’s capability to effectively employ Production Cost Modeling should be based upon:

- Robustness of the contractor’s processes and procedures for developing and validating a PCM.
- Maturity of the documentation and maintenance practices for configuration control of the PCM.
- Status of the contractor's preliminary model, if available.
- Past performance in developing realistic production cost models for similar systems.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.3 Design Trade Studies

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Basic trade study processes to be employed, including selection criteria for principal participants and integration of planned design trade studies and results into the IMP.
- Process for System Specification requirements allocation and flow down.
- Implementation of requirements for ST/STE/SE during the design process.
- Data pertinent to the prime contractor's and key suppliers' past performance in accomplishing design trade studies, with emphasis on such studies performed under the IPT concept, including metrics which identify performance with respect to cost, schedule and product performance.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Design Trade Studies should be based upon:

- Established processes for performing and documenting design trade studies and the planned integration of design trade studies and results into the IMP.
- Established process for System Specification requirements allocation and flow down.
- Established processes for addressing the ST/STE/SE requirements as part of the design trade study process
- Past performance of prime contractor and key suppliers in accomplishing design trade studies, with emphasis on such studies performed under the IPT concept.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.4 Specifications and Standards Management

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the achievement of the goals of this practice will be ensured, including the following:

- The processes established for development, use, and maintenance of performance specifications, along with relevant past performance data
- Processes, documentation practices, and past performance for requirements flowdown and design configuration control.
- Evidence of the use of performance based specifications in dealing with suppliers.
- Drawing and documentation standards employed.
- Evidence of the use of commercial parts, practices, and processes; and any pertinent experience with Single Process Initiatives.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Specifications and Standards Management should be based upon:

- Past performance in the development, use, and maintenance of performance specifications.
- Past performance in requirements flowdown and configuration documentation and control.
- Processes established for requirement and performance specification flowdown to suppliers, along with relevant past performance data.
- Drawing and documentation standards employed.
- Past experience with and planned implementation of commercial parts, practices, and processes, and Single Process Initiatives.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.5 Manufacturing Capability Assessment and Risk Management

Proposal Instructions To Offerors (PIO) Guidance (Section L)

- The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following: The overall risk management process, including management of key supplier risks (both subcontractors and GFP suppliers)
- How the specific manufacturing risks will be addressed, including the metrics to be used and how risks will be documented and reported.
- How the risk management effort will be integrated with the overall systems engineering and IPD processes.
- Process capability database includes all key processes.
- Industrial base sustainment issues.
- Effective minimization of all hazardous materials.
- Inclusion of the environmental assessment task in the Integrated Master Plan.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ risk management for the assessment of manufacturing capabilities should be based upon:

- Identified process capabilities of the prime and key suppliers, with linkage to process requirements.
- Inclusion of all shortfall items in the Risk Management Plan, the IMP, and/or the program schedule.
- Addressing of supplier capacity constraints and industrial base sustainment issues in the Risk Management Plan.
- Addressing environmental assessments and environmental impacts.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.6 Key Suppliers

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for evaluation and selection of key suppliers, including suppliers of GFP.
- Processes for integration of key supplier activities into the overall program plan, including a description of the tasks involved and key events with their exit criteria, to assure that supplier activities support the overall program performance.
- Processes for flowdown of performance specifications and key characteristics.
- Data pertinent to key supplier past performance in areas such as product performance, process performance, manufacturing capabilities, customer satisfaction, and schedule adherence.
- Contractor past performance in the management of supplier schedules and involvement of key suppliers in IPTs.
- Key supplier plans for the implementation of defect prevention processes and techniques.
- Processes for integration of key supplier risk management efforts with the program risk management effort.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively Manufacturing Capability and Risk Assessment processes should be based upon:

- The extent to which a disciplined, structured, and defined process is used for evaluation and selection of key suppliers.
- The extent to which a disciplined, structured process is used for the integration of key supplier events and activities into the IMP and for requirements flowdown.
- Effective methodologies for key characteristics and performance specifications flowdown.
- Evidence of past performance in the management of supplier schedules and involvement of key suppliers in IPTs.
- Key supplier experience in (or training plan for) the use of defect prevention processes and techniques.
- Past performance of key suppliers in cost, schedule, quality, and customer satisfaction.
- Key supplier risk assessment and risk mitigation plan.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.7 Key Characteristics and Processes

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Detailed description of a design system which includes identification of key product characteristics, identification of key production processes, balancing of key product design requirements to production process capabilities, identification of key process parameters and verification methods.
- The availability of established and validated process control tools and practices.
- Data pertinent to prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Key Suppliers practices should be based upon:

- The extent to which a disciplined, structured, and demonstrated process is used for requirements allocation and identification of key product characteristics, key process parameters, and product/process matching.
- The availability of established and validated process control tools and practices.
- Evidence of prime contractor and key supplier past performance in key product characteristics and key process parameters identification.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.8 Variability Reduction

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Approaches to variability reduction, product/product matching, and process control.
- intended metrics and the rationale for the use of attributes data, if proposed in lieu of variables data
- Evidence of the availability and use of process control tools and techniques
- Planning for key supplier flowdown of VR methods and requirements.
- Data pertinent to prime contractor and key supplier past performance in variability reduction, product/process matching, and process control.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Variability Reduction processes should be based upon:

- Evidence of prime contractor and key supplier past performance and capabilities in variability reduction, product/process matching, and process control.
- Maturity of the VR process as reflected in the intended metrics and the selection of variables versus attributes data.
- Availability of established and validated process control tools and practices
- Availability of personnel, at prime contractor's and key supplier's facilities, trained in variability reduction and process control techniques; and/or availability of effective training resources.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.9 Long Lead and Non-Recurring Activities

Proposal Instructions to Offerors (PIO) Guidance (Section L)

- The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following: The timing of and need for long lead and non-recurring equipment and activities.
- The relationship of ST/STE/SE to key characteristics and key processes.
- The rationale for key events which support the exit criteria.
- ST/STE/SE development in parallel with and as an integral part of development of the prime item.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage long lead and non-recurring activities should be based upon:

- An LRIP production plan and schedule which address long lead items, ST/STE/SE, and capital requirements to support LRIP activities occurring in EMD.
- LRIP production planning which supports key characteristics and key processes.
- Identification of and planning for long lead items.
- Risk management planning integrated into IMP and IMS.

CHAPTER 8. EMD PHASE REQUEST FOR PROPOSAL GUIDELINES

8.10 Product and Process Validation

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- The level of product and process validation effort.
- Simulations and incremental verification and validation processes to proof new tools and processes throughout the development cycle.
- The resources available, the maturity of the products and processes involved, and the level of success of other program events.
- Integration of the line proofing effort into the overall risk management effort.
- Plans for providing guidance on ST/STE/SE validation, and the level of product and process validation effort expected from suppliers.
- Identification of key product and process validation activities in the IMP and in risk management planning.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage product and process validation activities should be based upon:

- Incremental verification and validation throughout the design process.
- Integration with the risk management plan.
- Use of simulations for verification and validation in virtual environments.
- Demonstrating producibility and production readiness as well as lowered risk and cost through previous experience with simulation and incremental verification and validation.

CHAPTER 9. PRODUCTION PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

9.2 Manufacturing Process Control and Continuous Improvement

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Methods for manufacturing process control and implementation of continuous improvement.
- Procedures for continuous collection and review of data to identify improvement opportunities.
- Configuration control procedures to be employed for product design, ST/STE/SE, production methods and plans, and manufacturing planning.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage Manufacturing Process Control and Continuous Improvement activities should be based upon:

- Demonstrated understanding of the concepts of manufacturing process control and continuous improvement of manufacturing processes.
- Disciplined approach to controlling manufacturing processes, continuously seeking and identifying opportunities for improvement, and implementing process improvements.
- Documentation of past experience/performance in this area.

CHAPTER 9. PRODUCTION PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

9.3 Key Suppliers

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Integration of key supplier activities, including suppliers of GFP, into the overall program plan, with descriptions of the tasks involved and events (with their exit criteria) to be tracked to assure that supplier activities support overall program performance.
- Supplier capabilities or training in the use of defect prevention processes and techniques such as variability reduction.
- Contractor processes and practices for the management of supplier schedules and for involvement of key suppliers in IPTs.
- Integration of risk management efforts at key suppliers with the program risk effort.
- Flowdown of performance specification and key process characteristics and key product .characteristics.
- Data pertinent to past performance of key suppliers in areas such as product performance, process performance, manufacturing capabilities, customer satisfaction, and schedule adherence.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ Key Suppliers practices should be based upon:

- The extent to which a disciplined, structured process is used for the integration of key supplier events/activities into the IMP.
- Effective practices for key process characteristics and key product characteristics flowdown to suppliers.
- Evidence of past performance in the management of supplier schedules with emphasis on involvement of key suppliers in IPTs.
- Key supplier experience or training for the use of defect prevention processes and techniques.
- Key supplier past performance in cost, schedule, quality, and customer satisfaction.
- Key supplier risk assessment and risk mitigation planning.

CHAPTER 9. PRODUCTION PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

9.4 Variability Reduction

Proposal Instructions To Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following

- Approaches to variability reduction and process control, including the availability of validated process control tools and intended metrics.
- Availability of, or training plan for, personnel at prime contractor's and key supplier's facilities trained in variability reduction and process control techniques.
- Data pertinent to prime contractor and key supplier past performance in variability reduction, and process control, in particular as related to EMD and LRIP results.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively employ IPPD processes should be based upon:

- Availability of established and validated process control tools and practices and appropriateness of intended metrics.
- Availability of personnel, at prime contractor's and key supplier's facilities, trained in variability reduction and process control techniques, and/or availability of effective training resources.
- Evidence of prime contractor and key supplier past performance in process control and variability management.

CHAPTER 9. PRODUCTION PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

9.5 Factory Efficiency

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Demonstration of an ongoing production phase commitment to affordability, and a sensitivity to total acquisition costs, capacity constraints, and industrial base issues.
- Sustainment during the production phase of the open environment created by the IPT processes in the preceding phases of the program.
- Direct participation of manufacturing engineering in the decision processes associated with quality metrics, economic trade studies, and make vs. buy decisions.
- Functioning of the Program Office's manufacturing engineering representative as a member of the IPT, communicating directly with the Program Office with respect to opportunities to improve factory efficiency, contract effectiveness, requirements modifications, schedule changes, and other areas.

Evaluation Criteria Guidance (Section M)

Evaluation of the contractor's capabilities in the area of factory efficiency and lean manufacturing should be based on:

- Continued reduction of the AUPP for each procurement.
- Effective contractor and Program Office monitoring of changes to the product and the production processes to ensure that product performance is not sacrificed in the continuing effort to improve factory efficiency, or vice versa.
- Maintenance of the basic disciplines of change management, revalidation and reverification of key characteristics, and the protection of essential functions in the infrastructure.

CHAPTER 9. PRODUCTION PHASE REQUEST FOR PROPOSAL (RFP) GUIDELINES

9.6 Product Improvement

Proposal Instructions to Offerors (PIO) Guidance (Section L)

The PIO should ask the offeror to describe how the objectives of this practice will be pursued, including the following:

- Processes for managing and controlling design, product, and process configuration .
- A block change plan.
- The Production Cost Modeling process.
- Prior experience in managing product improvement initiatives in production programs.
- Applicable key supplier processes for managing and controlling design, product, and process configuration.

Evaluation Criteria Guidance (Section M)

Evaluation of an offeror's capability to effectively manage product improvement processes should be based upon:

- An established and effective configuration management process as it relates to product improvements.
- A documented Block Change Plan.
- A Production Cost Model developed in EMD and maintained for production.
- The past performance of the prime contractor and key suppliers in initiating and managing product improvements, including related configuration and cost management requirements.